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PETROGRAPHIC ANALYSES OF COAL CONVERSION FEEDSTOCKS AND RESIDUES

Phase III 1981/82

Final Report

by

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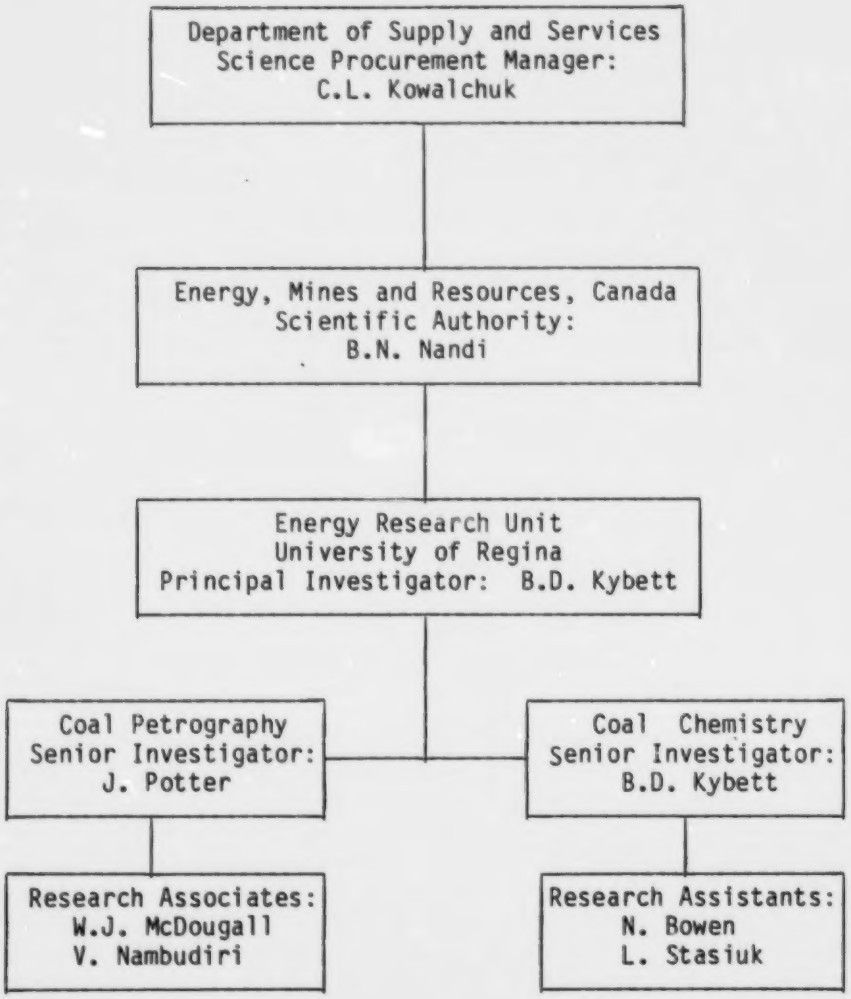

ABSTRACT

Laboratory scale gasification experiments were carried out on oxidised coals. The feedstocks and chars were petrographically analysed, and the analyses correlated with the behavior of the coals during gasification.

Three representative coals were studied, a lignite from Saskatchewan (Estevan), a sub-bituminous coal from Alberta (Whitewood) and a bituminous coal from Alberta. Each coal was oxidised under 3 conditions, ranging from mild to very severe (100°C for 60 hours, 225°C for 20 hours and 225°C for 60 hours). The feedstocks and the oxidised coals were gasified in a laboratory scale isothermal gasification apparatus in an air/steam atmosphere at 1 atm (0.1MPa) for three residence times.

The feedstocks, and the coals oxidised at 225°C for 20 minutes, were also charred under nitrogen at 500°C. The chars were gasified at 800°C in an air/steam atmosphere.

Petrographic analyses were made of the feedstocks, oxidised coals, charred coals and the residue chars from the gasification experiments. the gaseous and solid products of the gasification experiments were also chemically analysed.

The petrographic analyses are correlated with the preoxidation and gasification conditions.

ABBREVIATIONS

A.S.T.M.	American Society for Testing and Materials
E.R.U.	Energy Research Unit, University of Regina
R_o	Random refectance in oil, as a percentage
R_oAv	Average or mean refectance in oil, based on a minimum of fifty measurements
Std. Dev.	Standard deviation from the mean
S.N.G.	Substitute natural gas

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CHAPTER 1

INTRODUCTION

Coal as an energy resource has been generally neglected mainly because solid fuels are inconvenient to use but diminishing supplies of readily accessible crude oil and natural gas, coupled with increasing consumption, have revived interest in coal conversion to oil and SNG. Canada has relatively large, untapped reserves of low rank coal. The low grade lignites of southern Saskatchewan and sub-bituminous coals of Alberta are attractive as feedstocks for gasification. They are relatively abundant, cheap to mine and chemically reactive. Unfortunately they vary in chemical behaviour between mines, within mines and even within a single seam. Commonly they are oxidised, in situ.

Previous chemical reactivity and petrographic studies of Saskatchewan lignites and their residues from gasification experiments in Phase I showed (Energy Research Unit, 1980) that lignite macerals responded differently during gasification. Some reactive macerals reacted at the beginning of the process, whilst the reaction of others was delayed. This corresponded to early methane and hydrogen production, followed by carbon monoxide suggesting that the initial reactions involve mainly devolatilization, rather than gasification. This possibility was investigated in a second study, Phase II, (Energy Research Unit, 1981) using a series of sub-bituminous coals from Alberta. Their behaviour was compared with that of the lignites investigated in Phase I.

Many Western Canadian coals have been oxidised in-situ. Oxidation not only affects the heating value but also the chemical reactivity. In this project the effect of various levels of oxidation on the chemical

reactivity (gasification) of three coals (lignite, sub-bituminous and bituminous) were investigated petrographically. The aim was to explore the possibility of using petrography as a tool for predicting the behaviour of different coal feedstocks during gasification and for measuring levels of oxidation in the feedstock.

CHAPTER 2

EXPERIMENTAL PROCEDURE - GASIFICATION

2.1 Gasification experiments

Coal samples were gasified in a laboratory bench scale gasification apparatus. This was described in detail in the report on Phase 1 of this work (Energy Research Unit, 1980).

The system was designed to gasify small (10 g) samples of coal under uniform and carefully controlled conditions, primarily in order to obtain well defined residues for petrographic analyses. The apparatus, in order to reduce costs, operated at atmospheric pressure. This was acceptable since it was not to be used to acquire engineering data. Its operation was compared, in Phase II, with a more conventional fixed bed gasifier working at elevated pressures.

The reactor (Figure 2.1) consisted of a horizontal 1 m length of fused silicon tube, 2 cm in diameter. This was mounted inside two 30 cm tube furnaces. The reactor was connected to the inlet and exhaust manifolds by ball and socket joints with Teflon liners. This allowed it to be rotated, by a geared electric motor, around its horizontal axis at speeds up to 10 s^{-1}, to mix its contents.

The inlet manifold consisted of pressure reducing valves, pressure regulators, flowmeters and steam generators, which enabled a known flow of air (or oxygen) to be mixed with a known flow of steam, and passed into the reactor at a pressure slightly (50 Torr) above ambient.

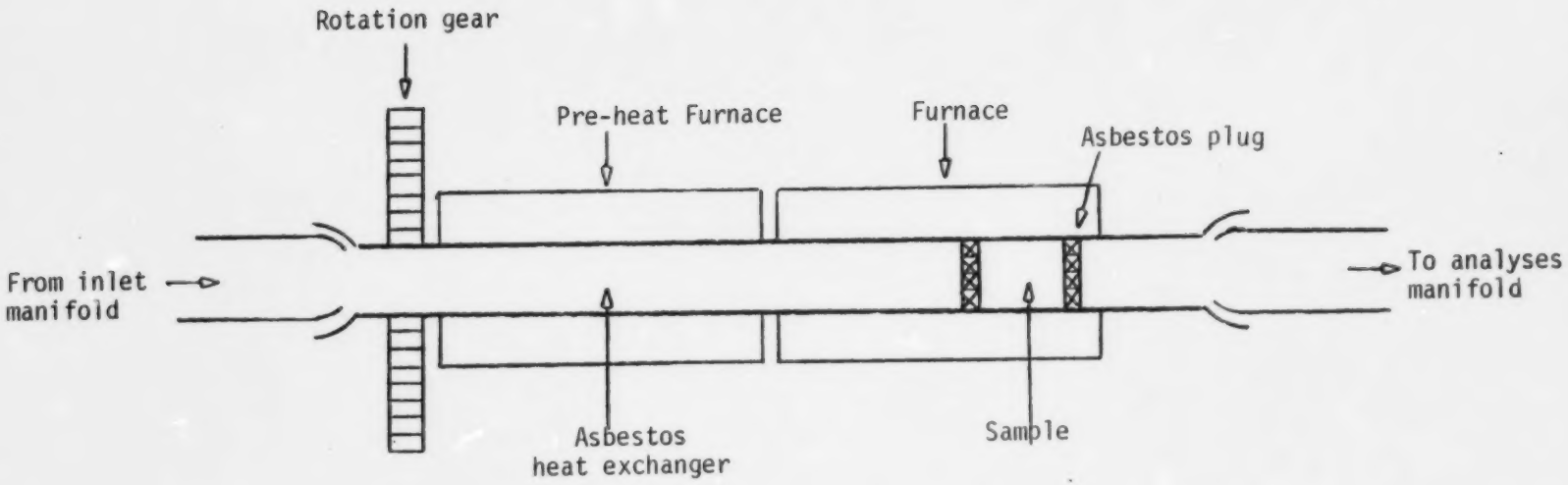


TABLE 2.1

Gasification Apparatus

The exhaust manifold consisted of a cold trap (-10°C) to remove bulk water, flowmeters, and a gas sampling system. Chemical analyses of the gas were done with a Carle Model 111-H (Application 158-H) gas chromatograph. This turnkey system for refinery gas analyses (effectively six columns with a hydrogen transfer tube) analysed for H_2, CH_4, C_2H_6, C_2H_4, $C_3 + C_4$, CO_2, CO, H_2S, SO_2, O_2, N_2 and H_2O.

The procedure consisted of weighing out a sample (10 g) of coal, 10-60 mesh. This was placed in the reactor, and held by mineral wool plugs. The reactor was placed in the (preheated) tube furnaces, and connected to the inlet and exhaust manifolds. The previously established flow of air (or oxygen) and steam was passed through the coal, which reached the reaction temperature within 3-4 minutes.

Known volumes of air (or oxygen) and steam were preheated to 500°C and passed through the coal. The rotation of the furnace ensured even reaction. The temperature of the exhaust gases (and by inference the reacting coal) was measured by a sensitive thermocouple axiallly mounted in the reactor, with its tip close to the reaction zone. The exhaust gases were passed through a cold (-5°C) trap to remove water, and their amount (P, V, T measurements) and chemical compositions determined.

A set of typical results is given in Table 2-1. The mass balance (84%) is relatively poor. This is due to incomplete recovery of char from the reaction tube, incomplete recovery of tar, which coated the inside surfaces of the exhaust manifold, and incomplete recovery of gases, due mainly to leakage at the rotating joints.

Eliminating or substantially reducing these losses would have made the apparatus unacceptably complicated. It was not necessary because the composition, not the yields, of the products were of prime concern.

TABLE 2.1

GASIFICATION OF SUB-BITUMINOUS COAL IN AN AIR/STEAM ATMOSPHERE AT 800°C

Reactants

Feedstock: Whitewood coal, mass 10.02 g, moisture content 0%

Air Flow: 100 mL min^{-1} at 25°C and 860 Torr (0.13 g min^{-1})

Water Flow: 0.26 g min^{-1}

Reaction Conditions

Pre-heat Furnace 500°C

Reaction Furnace 800°C

Products

Char: 6.37 g

Tar: 0.28 g

Time min	FLOW RATE mL min^{-1}	CO	O_2	N_2	H_2	CH_4	C_2H_6	C_2H_4	CO_2
2	300	5.5	15.6	1.8	0.7	27.0	20.6	2.7	26.1
4	2040	19.0	26.4	1.2	1.4	23.8	24.5	-	3.8
6	293	35.0	9.0	-	-	1.2	27.6	0.5	26.7
9	145	14.9	-	-	-	-	28.8	2.4	53.9

TABLE 2.1 .... continued

Yield of Product gases (g)

H_2	0.042
CH_4	0.27
C_2H_6	0.03
C_2H_4	0.02
CO	0.74
CO_2	0.69
Total	1.79

% Recovery as Products

Char = 63.6% of Feedstock, dry weight basis

Tar = 2.8% of Feedstock, dry weight basis

Gases = 17.9% of Feedstock, dry weight basis

Total recovery (excluding water) = 84%

2.2 Chemical Analyses

A limited number of chemical analyses were done on the feedstocks and products of gasification. The methods used are described below. The results are given in the Appendices and where relevant in this report, and are not separately reported or discussed in Chapter 4.

Heating Value (Calorific Value)

The heating value of the solid samples was determined using a Parr Model 1261 adiabatic jacket bomb calorimeter, equipped with a Hewlett Packard Model 2081A quartz thermometer. The ASTM:D 3286 procedure was followed, with a reproducibility of better than 0.2%.

The sulphur in the analysis sample was determined by the ASTM:D 3177 Method B (bomb washing method) during the determination of the heating value.

Proximate Analysis, Solid Product

i) Moisture - ASTM:D 3173 procedure

ii) Volatile Matter - ASTM:S 3175-77 procedure

iii) Ash - The dried sample from the moisture determination was used to determine the ash content, following the ASTM:D 3174 procedure.

Carbon, Hydrogen and Nitrogen Analysis

This was determined by the Saskatchewan Research Council, Saskatoon, using a Perkin Elmer Model 240B elemental analyser.

Chemical Composition, Gaseous Products

The product gases were analysed using a Carle Model 111-H (Application 158-B) gas chromatograph. This turnkey system analysed for H_2, CH_4, C_2H_6, C_2H_4, $C_3 + C_4$, CO_2, CO, H_2S, SO_2, O_2, N_2 and H_2O.

Chapter 3

EXPERIMENTAL PROCEDURE - PETROGRAPHIC ANALYSES

3.1 Sample collection

A lignite sample SV-13 was collected from the Souris Valley Mine near Estevan, Saskatchewan (Figure 3.1), with cooperation of the Saskatchewan Power Corporation. The sample was collected from a freshly exposed 2.4 m thick clarain seam with 11.0 m to 12.1 m overburden, W.C.S.C. location: Section 14; Township 2; Range 8; West of 2nd meridian, stored in nitrogen and refrigerated.

The sub-bituminous coal sample was collected from the Whitewood Mine in the eastern plains region of Alberta (Figure 3.1), in 1980 with cooperation of Manalta Coal Ltd. Sampling details were reported in Phase II (Energy Research Unit, 1981). This sample was also stored in nitrogen and refrigerated to prevent deterioration.

The medium-volatile bituminous coal sample CV-1 was obtained from Energy, Mines and Resources, Edmonton, Alberta.

3.2 Petrographic Procedures

3.2.1 Sample Preparation

All coal and residue samples were prepared using standard A.S.T.M. methods. They were crushed and separated by riffling to obtain representative samples, and made into 1 inch blocks using epoxy resin. The samples were then polished according to the medhod described in Phase II (Energy Research Unit, 1980).

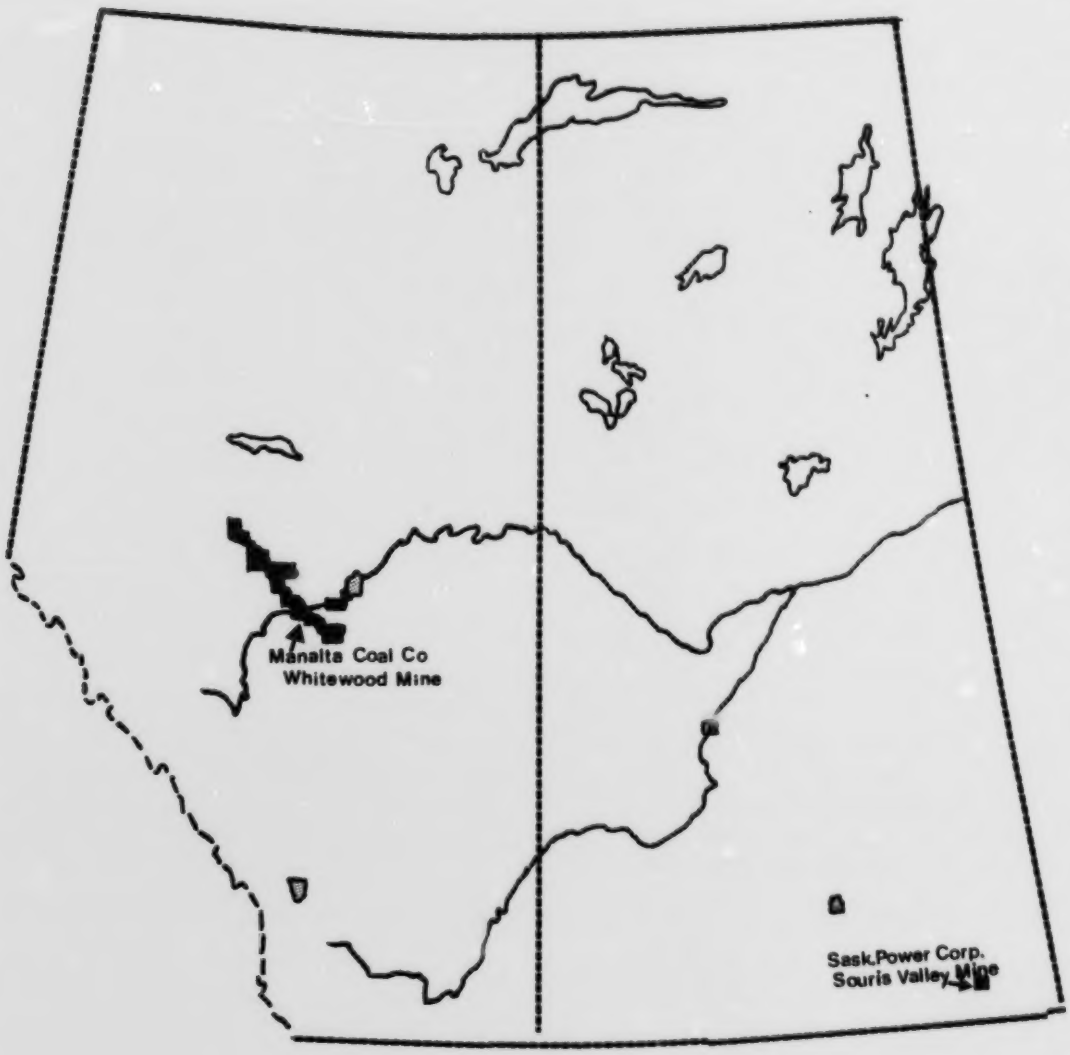


FIGURE 3.1

Sample collection sites of

Saskatchewan lignite and

Alberta sub-bituminous coals

3.2.2 Petrographic Analysis

Coal and char samples were observed using a Leitz 'Dialux' polarizing, reflected light microscope equipped for brightfield and fluorescent light microscopy using oil immersion objectives. Quantitative analyses included:

1) Compositional analysis by point counting using a 'Swift' automatic point counter with a Leitz "click-stop" stage

2) reflectance measurements using a Leitz 'Orthoplan' polarizing reflected light microscope equipped with an MPV II compact microscope photometer and digital display unit, and oil immersion objectives

3.2.3 Nomenclature

Lignite maceral analyses were done according to the International Committee for Coal Petrology (I.C.C.P) using their nomenclature for brown coals (Table 3.1). Additionally the terms strucutred, unstructured, and groundmass huminite (Cameron & Birmingham, 1971) are used to collectively describe huminite macerals (Energy Research Unit, 1980, 1981). The I.C.C.P. nomenclature for hard coals (1963, 1975) is applied to the sub bituminous and high-volatile bituminous coals.

Classification of the components of the gasification residues is based on morphology, origin and optical character (isotropic or anisotropic). The anisotropy displayed by huminite/vitrinites was a basic anisotropy or a mosaic texture (Table 3.3).

Huminites, found in lignites, are the precursors of vitrinite in hard coals. It is common when discussing lignites, sub-bituminous coals and high volatile bituminous coals collectively to refer to these materials as: huminite/vitrinite.

Group Maceral	Maceral Type*	Maceral	Submaceral+
Huminite	Structured Huminite	Textinite	
		Ulminite	Texto-ulminite Eu-ulminite
	Groundmass Huminite	Attrinite Densinite	
	Unsaturated Huminite	Gelinite	Porigelinite Levigelinite
		Corpohuminite	Phlobaphinite Pseudophlobaphinite
Liptinite		Sporinite Cutinite Resinite Suberinite Alginite Liptodetrinite Chlorophyllinite	
Inertinite		Fusinite Semifusinite Macrinite Sclerotinite Inertodetrinite	

+ incomplete, can be expanded as desired

TABLE 3.1

I.C.C.P. Nomenclature Applied to Brown Coals (1971), Modified*.

Maceral Group	Maceral	Maceral Type*	Submaceral	Old Nomenclature
	Telinite	Structural	Telinite 1 Telinite 2 Telocollinite	Vitrinite A
	Collinite	Unstructured	Gelocollinite Corpocollinite	
	Vitrodetrinite	Groundmass	Desmocollinite	Vitrinite B
Liptinite	Sporinite Resinite Cutinite Alginite Liptodetrinite			Exinite
Inertinite	Fusinite Semifusinite Macrinite Sclerotinite Inertodetrinite		Pyrofusinite Degradofusinite	

+ incomplete, can be expanded as desired

TABLE 3.2

I.C.C.P Nomenclature for Hard Coals

(1963, 1971), Modified*.

Isotropic	Huminite/Vitrinite Inerts
Anisotropic	Huminite/Vitrinite - Basic Huminite/Vitrinite - Mosaic Inerts
Mineral Matter	

Summary:

Total Isotropic Total Anisotropic Total Mineral Matter	Total Vitrinite Total Inerts Total Mineral Matter

TABLE 3.3

Classification of Gasification Char Constituents

CHAPTER 4

PETROGRAPHY OF FEEDSTOCKS

Petrographic analyses of the three feedstocks are given in Table 4.1 and shown graphically in Figure 4.1. Each feedstock was huminite/vitrinite rich containing 79.7% - 82.0% of these macerals. The Whitewood sample was dominantly composed of structured vitrinite, 61.5%, while the Souris Valley and CV samples contained more groundmass huminite/vitrinite, 34.0% and 31.7% respectively. The CV feedstock comprised 19.8% inertinite; semifusinite was dominant. The Whitewood sample contained 15.8% inertinite compared to 12.7% for the Souris Valley feedstock. Liptinite contents were low for both the Souris Valley, 4.0%, and Whitewood, 1.7%, samples; no liptinite was recorded in the CV sample.

Reactives: inerts ratios (Shapiro, Gray and Eusner, 1961), for the three coals are shown in Table 4.1. The Souris Valley sample had the highest ratios, (6.6), and the CV sample the lowest (5.5), although the values for the three coals were similar.

Reflectance (R_0AV) values for the three feedstocks are given in Table 4.1. The Souris Valley sample had a reflectance of 0.32%; this is similar to values previously recorded on Souris Valley coal and lignites from the Estevan area in general (Energy Research Unit, 1980). The Whitewood sample had a reflectance of 0.35%. This is 0.03% lower than when the Whitewood coal was originally analysed (Energy Resarch Unit, 1981). This sample was the same as used in last year's devolatilisation/gasification experiments; the presence of micropores and micro-

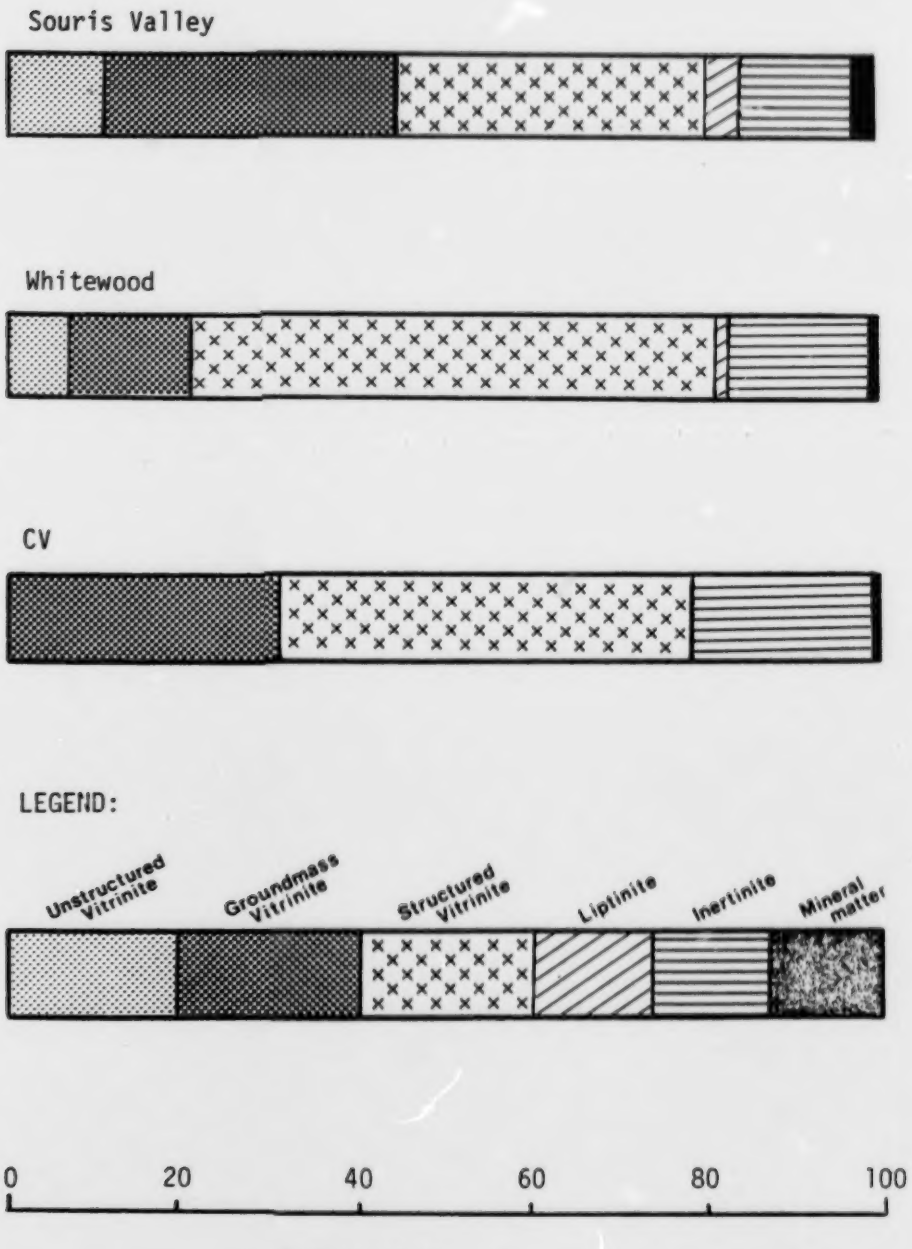
Sample	Souris Valley	Whitewood	CV
Maceral Group Analysis			
Huminite/Vitrinite:			
Structured	36.3	61.5	48.0
Unstructured	10.7	6.5	--
Groundmass	34.0	14.0	31.7
Liptinite	4.0	1.7	--
Inertinite	12.7	15.8	19.8
Mineral Matter	2.3	0.5	0.5
	100%	100%	100%
Reactives: Inerts Ratio			
Ratio	6.6	6.4	5.5
Reflectance R_O, AV	0.32	0.35	1.16

TABLE 4.1

Petrographic analysis of coal feedstocks

FIGURE 4.1

Petrographic analyses of gasification feedstocks



fractures indicated that the coal had oxidised (Chandra, 1961). This would be a result of deterioration during storage, even though it was stored in nitrogen at 5°C (Energy Research Unit, 1980). This would also account for the low reflectance. The reflectance of the CV feedstock was 1.16%; this indicates a medium volatile bituminous coal; micropores and micrcracks were present in the vitrinite, indicating that this coal was also oxidised.

Proximate analyses of the three feedstocks are as follows:

Sample	% Volatiles	% Ash	Calorific Value (J/g)
Souris Valley	39	9.8	22510
Whitewood	38	5.8	26950
CV	16	6.9	33830

CHAPTER 5

DISCUSSION OF GASIFICATION EXPERIMENTS

5.1 Introduction

The Petrographic studies described in Chapter 6 were done on residues obtained from in-house gasification experiments. As was discussed in Chapter 2, the experiments were designed to be simple and on a small scale so that a large number of tests could be made economically, to provide well characterised residues obtained under a variety of conditions, for petrographic analysis. The experiments, in themselves, were not expected to provide new information on the chemical aspects of the gasification of coal.

5.2 Preparation of char and oxidised coals

Coals contain significant amounts of volatile matter, which is evolved as gas during the initial (heating) stages of gasification. These gases, rich in hydrogen and methane, can make a large contribution to the total heating value of the gases produced during the gasification of the coal. The two processes, devolatilisation and gasification are distinct, and some experiments were made with devolatised coal (char).

The feedstocks were devolatised by heating them at 600°C for 60 minutes in the gasification apparatus. Nitrogen, at a flow rate of 100 mL min^{-1}, was used to provide an inert atmosphere. The devolatised coals still contained (Table 5.1) small amounts of volatile matter. This was necessary since further devolatisation removed too much of the original structure of the coal for meaningful petrographic comparisions with the feedstocks to be made.

The chemical analyses of the devolatised feedstocks are given in Table 5.1.

The oxidised feedstocks were prepared by heating the ground coals, in an open dish, in an air oven with a convective air flow. Three sets of oxidising conditions were used:-

i) 60 hours at 100°C

ii) 20 hours at 225°C

iii) 60 hours at 225°C

These were chosen to provide mild, medium and very strongly oxidised coals. (Jensen et al., 1966)

TABLE 5.1 (a)

Chemical analyses of feedstocks and chars (dry basis)

SV-13 (lignite)	Volatiles %	Ash %	Fixed Carbon % (by diff.)	C %	H %	N %	Heating Value J g^{-1}
Feedstock	38.4	9.3	52.3	47.8	4.1	1.2	22,510
Devolatised Char	4.5	14.8	80.7	60.9	2.0	1.1	24,490
Oxidised Feedstock:-							
i) 60 h at 100 C	30.2	10.8	59.0	----	----	----	28,820
ii) 20 h at 225°C	38.2	13.5	48.3	53.1	3.1	1.6	22,340
iii) 60 h at 225°C	39.5	16.3	44.2	47.0	2.3	2.2	18,060

TABLE 5.1 (b)

Chemical analyses of feedstocks and chars (dry basis)

Whitewood (sub-bituminous)	Volatiles %	Ash %	Fixed Carbon % (by diff.)	C %	H %	N %	Heating Value J g^{-1}
Feedstock	38.4	5.8	55.8	52.7	3.7	1.1	26,950
Devolatised Char	8.1	8.4	83.5	55.3	1.5	1.7	30,850
Oxidised Feedstock:-							
i) 20 h at 100 C	17.0	6.6	76.4	50.8	3.2	1.2	25,670
ii) 60 h at 225°C	36.2	6.0	57.8	54.6	3.4	1.0	25,550
iii) 60 h at 225°C	44.0	9.5	46.5	46.7	1.5	1.5	18,710

TABLE 5.1 (c)

Chemical analyses of feedstocks and chars (dry basis)

CV-1 (bituminous)	Volatiles %	Ash %	Fixed Carbon % (by diff.)	C %	H %	N %	Heating Value J g^{-1}
Feedstock	16.0	6.9	77.1	69.0	4.0	0.9	33,830
Devolatised Char	7.6	11.99	80.5	----	----	----	34,030
Oxidised Feedstock: -							
i) 60 h at 100°C	15.8	7.5	76.7	----	----	----	33,430
ii) 20 h at 225°C	22.3	7.1	70.6	65.3	2.4	1.1	27,960
iii) 60 h at 225°C	27.5	7.5	65.0	59.8	2.1	1.1	25,750

The mass changes during oxidation are shown in Table 5.2. There was a large decrease in mass with the lignite and sub-bituminous coal, 36% and 22% respectively, after oxidation for 60 hours at 100°C, and this had increased to 57% and 48% after oxidation for 60 hours at 225°c. The decrease in mass was also reflected in the ash analyses in Table 5.1 Since the minerals in the ash would not presumably be lost by volatilisation during the oxidation, the increase in ash after oxidising at 225°C for 60 hours indicates a mass loss of 75% for the lignite (compared with the 57% obtained on a different manner by direct weighing) and 64% for the sub-bituminous coals (48% by direct weighing).

TABLE 5.2.

Mass changes during oxidation

of feedstocks

	Mass change, %
SV-13 (lignite)	
After 60 hours at 100°C	-36
After 20 hours at 225°C	-49
After 60 hours at 225°C	-57
Whitewood (sub-bituminous)	
After 60 hours at 100°C	-22
After 20 hours at 225°C	-37
After 60 hours at 225°C	-48
CV-1 (bituminous)	
After 60 hours at 100°C	-4
After 20 hours at 225°C	+1
After 60 hours at 225°C	+2

Coal, especially low rank coal, oxidises at low temperatues, and significant oxidation occurs at 45°C (Nordon, 1979) and 35°C (Swann, 1979). Three oxidation ranges have been distinguished (Berkowitz, 1979). Below 70°C rates of oxidation are generally low, and independant of coal rank, and oxidation consists mainly of forming acid functional groups and peroxides. The second range from 70 to 150°C, follows a similar pattern except that the rate of oxidation is higher, and is controlled by oxygen diffusion within the coal. In the third range (above 150°C) rapid generation of humic acids occur - these do not decompose below 250°C.

Our first set of oxidising conditions (60 hours at 100°C) provided coals oxidised in the second range of conditions, and these should have had enhanced concentrations of acid and peroxide groups. The second set of oxidising conditions (20 hours at 225°C) would have provided coals with some oxidation to humic acid, the third set would have extended oxidation of the same type.

Other oxidising conditions could not be used because of budget restrictions. Other factors that affect oxidation, such as moisture, partical size and the partial pressure of oxygen and other gases, were also not investigated.

The chemical analyses of the oxidised feedstocks are given in Table 5.1, and show that considerable chemical changes had occurred. There was an increase in the amount of volatile matter, and a decrease in the heating value, with increase in oxidation, as expected.

5.3 Gasification experiments

Previous work, (Energy Research Unit 1981) indicated that the best single set of gasification paramenters to provide meaningful samples for

ication "reactions" were not significant at lower temperatures. Higher temperatures produced samples that had lost too much of their original characteristics for any correlations to be produced. The three feedstocks, and the devolatised chars and oxidised feedstocks were all gasified in an air/steam atmosphere at 800°C for three different residence times, 2, 6, and 20 minutes. The flow rates for the air and steam were 0.011 and 0.022 g min^{-1} per g of coal sample respectively.

It had been proposed that one residence time for the gasification experiment would be long enough to complete the gasification of the coal. This was so that the yields of gases, etc in our experiments could be composed with those in the literature, which are usually for "total gasification". "Total gasification", however, took too long, several hours, and of course gave a solid residue (ash) not suitable for coal petrographical analysis. Accordingly it was decided that it would be more advantageous to gasify the samples for a long residence time 20 minutes) that still, however, yielded a solid residue suitable for analysis.

The results of these experiments are given in Appendix III.

The variation in the yields of gaseous products with oxidation conditions are summarised in Table 5.3 for the gasification experiments with a 20 minute residence time. The sub-bituminous and bituminous coals showed similar behaviour, with a significant increase in the amount of CO_2 formed with increase in the severity of the oxidation. The lignite gave decreasing yields of CO_2 with increasing oxidation, because of the loss of volatiles during the oxidation process. The yield of CO followed the same pattern as CO_2. Smaller amounts of H_2 and CH_4 were formed, and the yield decreased with increasing oxidation of the feedstock.

TABLE 5.3

Variation of yield of gaseous products with oxidation conditions after gasification for 20 minutes

Oxidation conditions	Amount of gas, (g. per g. coal) x 100			
	H_2	CH_4	CO	CO_2
SV-13(lignite):				
After 60 hours, 100°C	0.8	2.4	7.3	10.6
After 20 hours, 225°C	0.4	0.3	6.7	2.6
After 60 hours, 225°C	0.4	0.2	2.5	3.5
Whitewood (Sub-bit):				
After 60 hours, 100°C	0.4	0.8	1.1	3.7
After 20 hours, 225°C*	0.1	0.4	---	0.9
After 60 hours, 225°C	0.5	0.4	2.8	8.9
CV-1 (bituminous)				
After 60 hours, 100°C	0.2	1.6	0.8	0.9
After 20 hours, 225°C	0.7	1.0	5.6	6.0
After 60 hours, 225°C	0.5	0.3	2.5	3.6

* low values (due to leak?)

CHAPTER 6

PETROGRAPHY OF FEEDSTOCKS AND RESIDUES FROM GASIFICATION EXPERIMENTS

6.1 Introduction

The coal feedstocks described in Chapter 4 (Souris Valley, Whitewood and CV) were each oxidised in the laboratory, under the conditions described in Chapter 5, producing pre-oxidised coal feedstocks which were subsequently gasified at constant temperature and pressure, with varying residence time. A total of nine preoxidized feedstocks and twenty-seven gasification residues were thus generated for petrographic analyses.

6.2 Petrography of Preoxidised Feedstocks

Petrographic analyses of the preoxidised feedstocks are given in Appendix I and shown graphically in Figures 6.1 to 6.3, proximate analyses are given in Table 6.1. The maceral composition of the preoxidised coals are all similar to their original feedstocks; those were discussed in Chapter 4. Oxidation of the coals for 60 hours at 100°C had little effect on the coal but when oxidised for 60 hours at 225°C, macerals were severely affected.

6.2.1 Oxidation for 60 hours at 100°C

Oxidising the coals for 60 hours at 100°C had little visible affect on the optical properties of the coal macerals in any of the samples. Liptinites were still present, they flouresced orange-brown under blue-violet light. No oxidation cracks were observed in the huminites/vitrinites, but the borders of some Whitewood and Souris Valley structured

Sample.	Oxidising Conditions time/temp.)	% Volatiles	% Ash	Calorific Value (J/g)
SV13.1	60 Hrs. 100°C	30.2	10.8	28820
SV13.6	20 Hrs. 225°C	38.2	13.5	22340
SV13.7	60 Hrs. 225°C	39.5	16.3	18060
WD.2	60 Hrs. 100°C	36.2	6.0	25550
WD1	20 Hrs. 225°C	17.0	6.6	25670
WD.3	60 Hrs. 225°C	44.0	9.5	18710
CV1.1	60 Hrs. 100°C	15.9	7.5	33430
CV1.2	20 Hrs. 225°C	22.8	7.1	27960
CV1.3	60 Hrs. 225°C	27.5	7.5	25750

Table 6.1

Proximate analyses of Preoxidised Feedstocks

huminite/vitrinite particles were more highly reflecting than the centers (Plate 1). The preoxidised CV sample closely resembled the original feedstock.

6.2.2 Oxidation for 20 hours at 225°C

Samples oxidised for 20 hours at 225°C showed considerable change from the original feedstocks. Micropores, microcracks and oxidation rims were present in the huminite/vitrinite of the preoxidised Souris Valley and Whitewood coals (Plates 2 and 3). In these samples, liptinite appeared in two forms:

1) dark grey in ordinary light (reflectance lower than huminite/vitrinite), flourescing orange-brown in blue-violet light.

2) medium to light grey in ordinary light (reflectance similar to or higher than huminite/vitrinite), no longer fluorescing in blue-violet light.

The disappearance of fluorescence shows the reaction of the liptinites.

The CV sample oxidised under these conditions displayed some micropores, microcracks and weak oxidation rims (Plate 4). These rims, however, were similar to those developed in the Souris Valley and Whitewood coals oxidised for 60 hours at 100°C rather than those oxidised for 20 hours at 225°C.

6.2.3 Oxidation for 60 hours at 225°C

Of the preoxidised coals, the samples oxidised for 60 hours at 225°C were most severely affected. Souris Valley and Whitewood samples displayed extensive cracking and strong oxidation rims around huminites/vitrinites (Plate 5), and the majority of the liptinites had reacted.

The huminite/vitrinite reflectance of the Souris Valley and Whitewood samples increased from 0.32% and 0.35% to 0.91% and 0.94%, respectively. The frequency of oxidation cracks and rims was greater in the CV sample oxidised at 225°C for 60 hours than in that oxidised at 225°C for 20 hours, but the overall extent of oxidation was less than in the other two preoxidised feedstocks (Plate 6).

6.3 Petrography of Gasified, Preoxidised Coal Residues

The preoxidised coals, Souris Valley, CV and Whitewood were gasified. Oxidation conditions, gasification residence times and char analyses are given in Tables 6.2 to 6.4. Char analyses are shown graphically in Figures 6.4 to 6.12. Reflectance data are shown in Tables 6.5 to 6.7 and proximate analyses are given in Tables 6.8 to 6.10. The residues from the Souris Valley samples preoxidised for 60 hours at 100°C, then gasified for 2, 6 and 20 minutes contained isotropic, charred material of which less than 2% was anisotropic material, mainly inertinite macerals, and mineral matter. The gasified residues of samples preoxidised for 20 hours and 60 hours at 225°C contained up to 68% of anisotropic material (Table 6.2 to 6.4) which exhibited a form of basic anisotropy and was developed in the reactives (huminite/vitrinite) as well as in the inerts (Plate 7). This may resemble the material that Goodarzi and Murchison (1976) describe as a general anisotropy that developes in carbonized preoxidised caking and coking coal vitrinites.

Samples gasified for 20 minutes contained in excess of 60% anisotropic material (Tables 6.2 to 6.4). Again a basic anisotropy developed in the huminite/vitrinite and formed dominantly around cracks and margins of particles. These were previously the areas where oxidation

Sample	Oxidising Conditions	Gasification: Residence Time	Isotropic Char Components	Anisotropic Char Components	Mineral
SV13.1	60 Hrs. 100°C	2 min.	99.7	-	0.3
SV13.1	60 Hrs. 100°C	6 min.	99.0	0.7	0.3
SV13.1	60 Hrs. 100°C	20 min.	97.7	1.7	0.6
SV13.6	20 Hrs. 225°C	2 min.	70.7	29.0	0.3
SV13.6	20 Hrs. 225°C	6 min.	52.7	47.0	0.3
SV13.6	20 Hrs. 225°C	20 min.	39.4	60.6	-
SV13.7	60 Hrs. 225°C	2 min.	90.0	9.7	0.3
SV13.7	60 Hrs. 225°C	6 min.	49.0	50.7	0.3
SV13.7	60 Hrs. 225°C	20 min.	36.0	63.7	0.3

Table 6.2

Petrographic analyses of preoxidised gasification residues

Sample	Oxidising Conditions	Gasification: Residence Time	Isotropic Char Components	Anisotropic Char Components	Mineral
WD.2.	60 Hrs. 100°C	2 min.	95.4	4.3	0.3
WD.2	60 Hrs. 100°C	6 min.	85.3	14.4	0.3
WD.2	60 Hrs. 100°C	20 min.	96.7	3.0	0.3
WD.1	20 Hrs. 225°C	2 min.	89.2	10.5	0.3
WD.1	20 Hrs. 225°C	6 min.	85.4	14.0	0.6
WD.1	20 Hrs. 225°C	20 min.	82.8	17.2	-
WD.3	60 Hrs. 225°C	2 min.	86.3	12.9	0.8
WD.3	60 Hrs. 225°C	6 min.	42.6	56.4	1.0
WD.3	60 Hrs. 225°C	20 min.	30.0	68.4	1.6

Table 6.3

Petrographic analyses of preoxidised gasification residues

Sample	Oxidising Conditions	Gasification: Residence Time	Isotropic Char Components	Anisotropic Char Components	Mineral
CV1.1	60 Hrs. 100°C	2 min.	20.0	79.3	0.7
CV1.1	60 Hrs. 100°C	6 min.	10.6	88.7	0.7
CV1.1	60 Hrs. 100°C	20 min.	9.0	90.0	1.0
CV1.2	20 Hrs. 225°C	2 min.	84.5	15.0	0.5
CV1.2	20 Hrs. 225°C	6 min.	79.0	20.5	0.5
CV1.2	20 Hrs. 225°C	20 min.	74.5	25.0	0.5
CV1.3	60 Hrs. 225°C	2 min.	77.0	22.7	0.3
CV1.3	60 Hrs. 225°C	6 min.	71.0	528.7	0.3
CV1.3	60 Hrs. 225°C	20 min.	73.0	26.3	0.7

Table 6.4

Petrographic analyses of preoxidised gasification residues

FIGURE 6.1

Petrographic analyses of pre-oxidised feedstocks

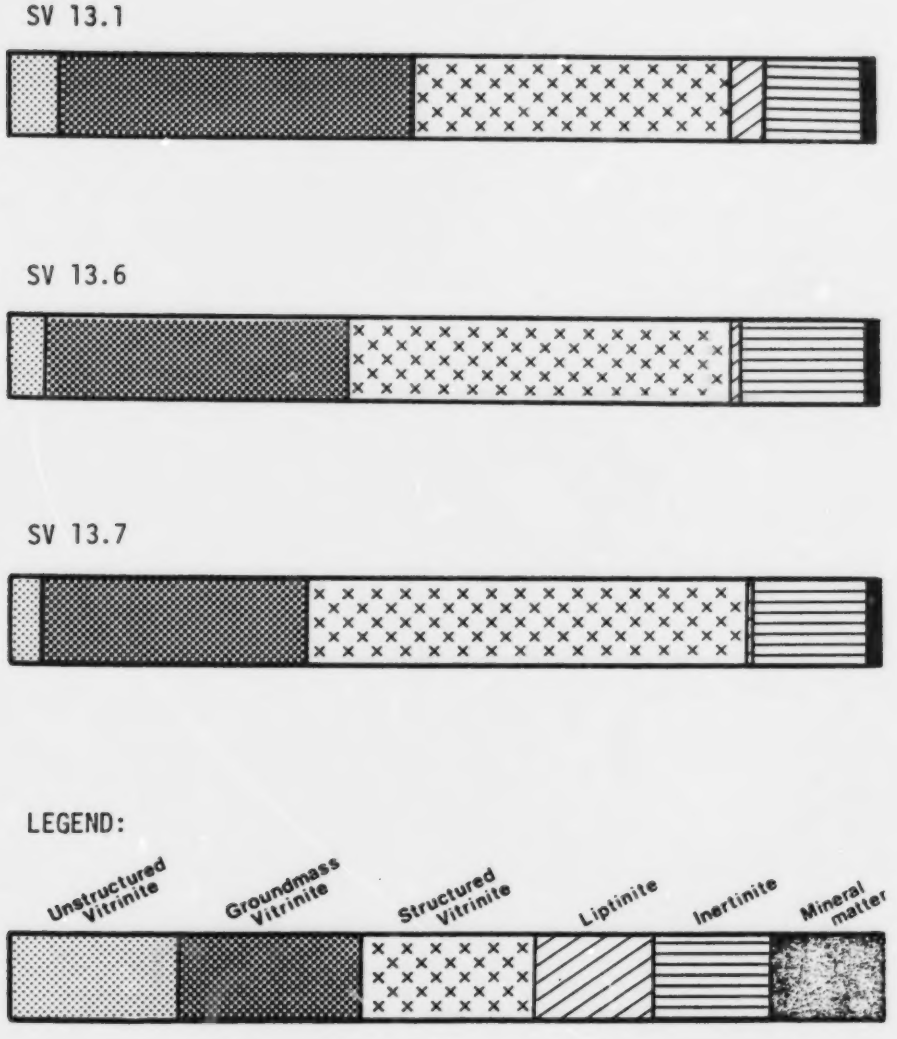


FIGURE 6.2

Petrographic analyses of pre-oxidised feedstocks

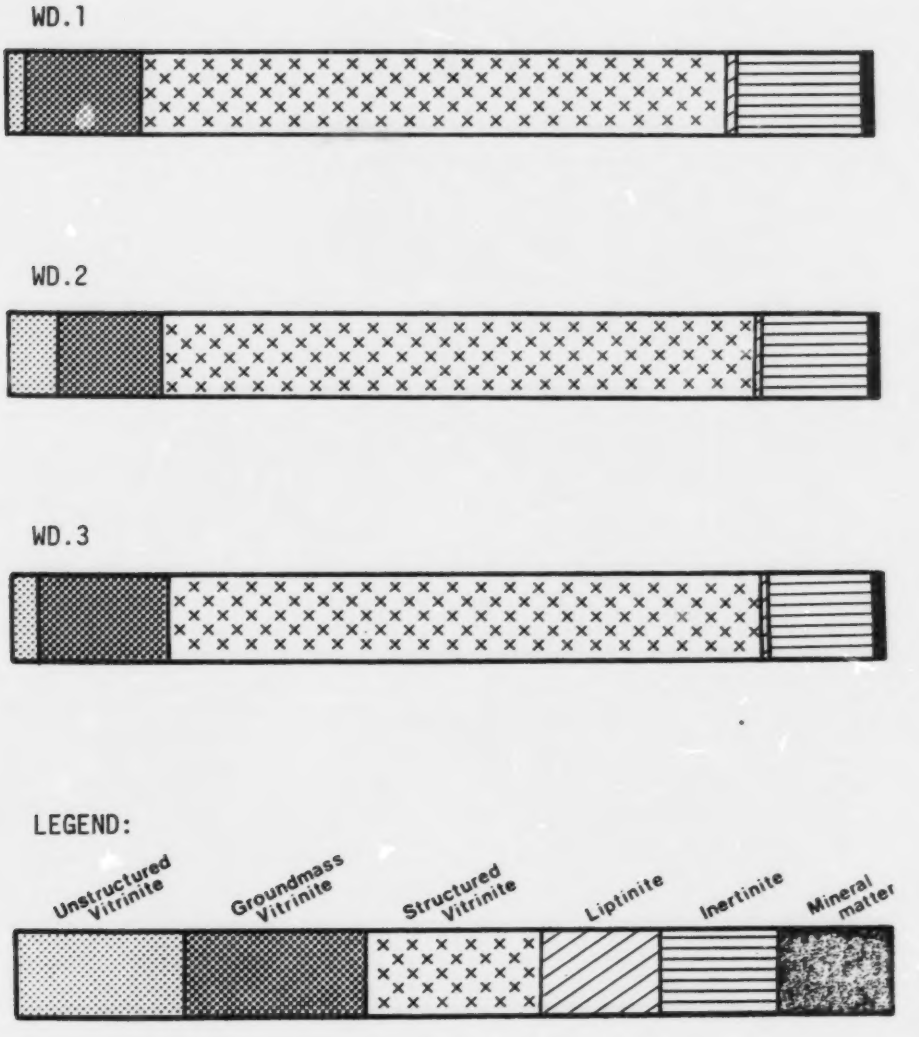


FIGURE 6.3

Petrographic analyses of pre-oxidised feedstocks

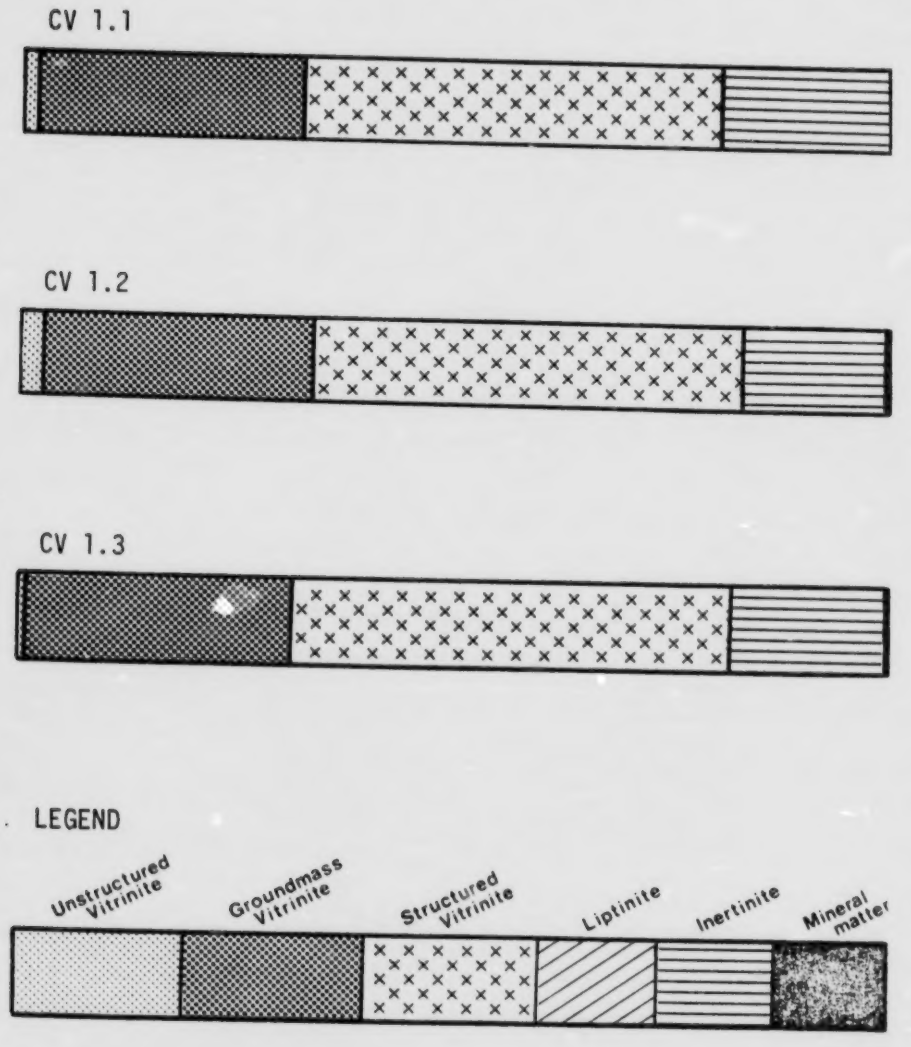


FIGURE 6.4

Petrographic analyses of gasification residues

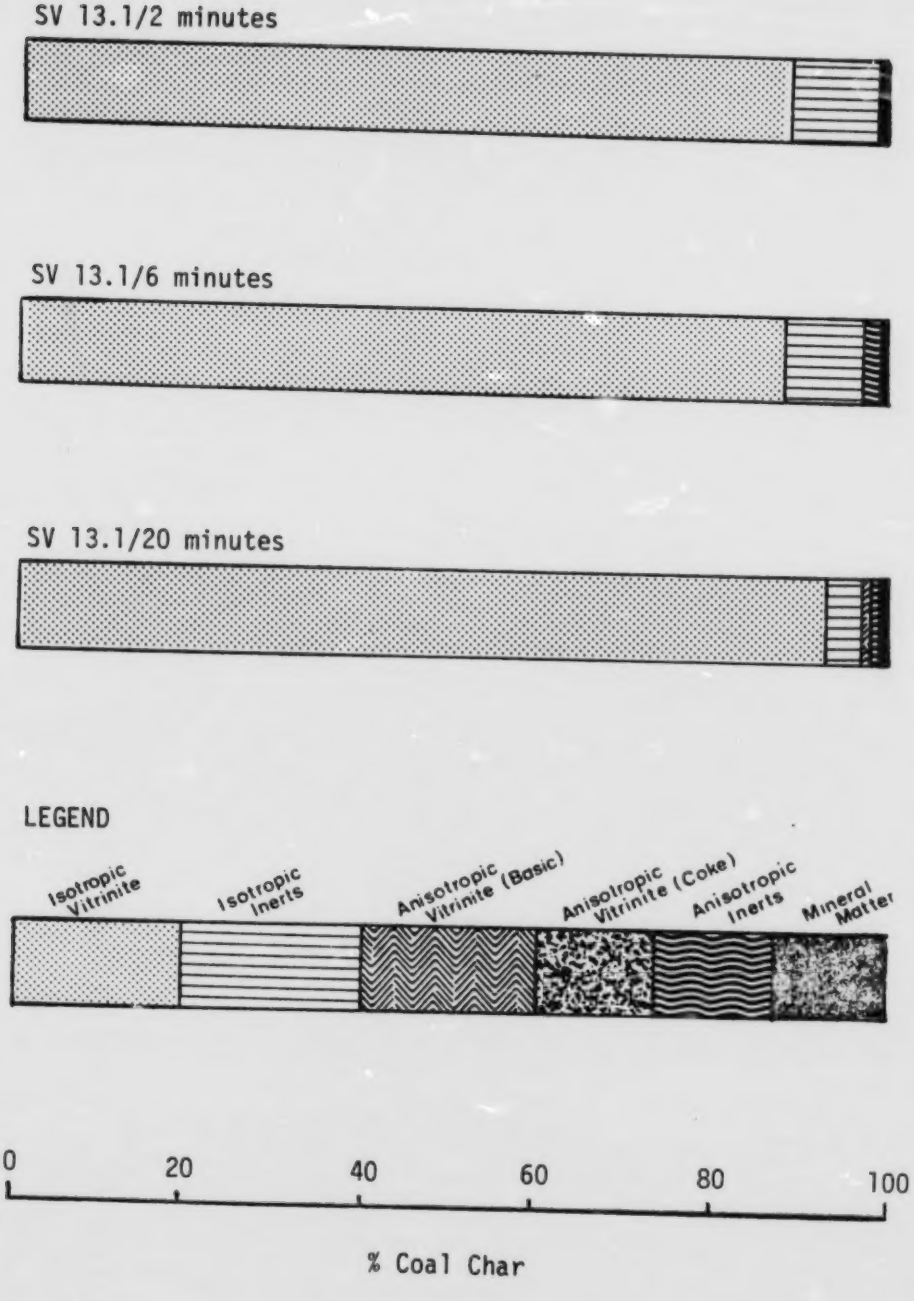


FIGURE 6.5

Petrographic analyses of gasification residues

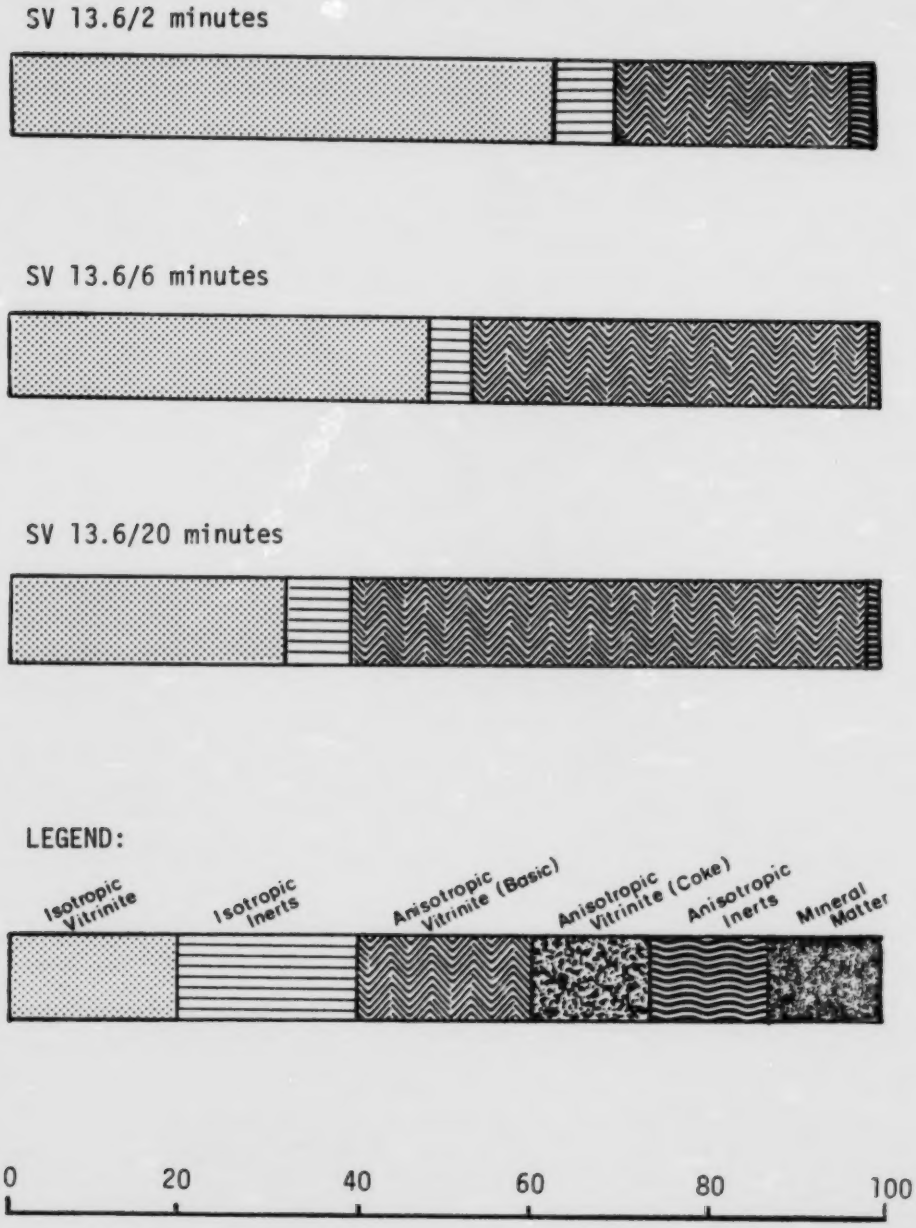


FIGURE 6.6

Petrographic analyses of gasification residues

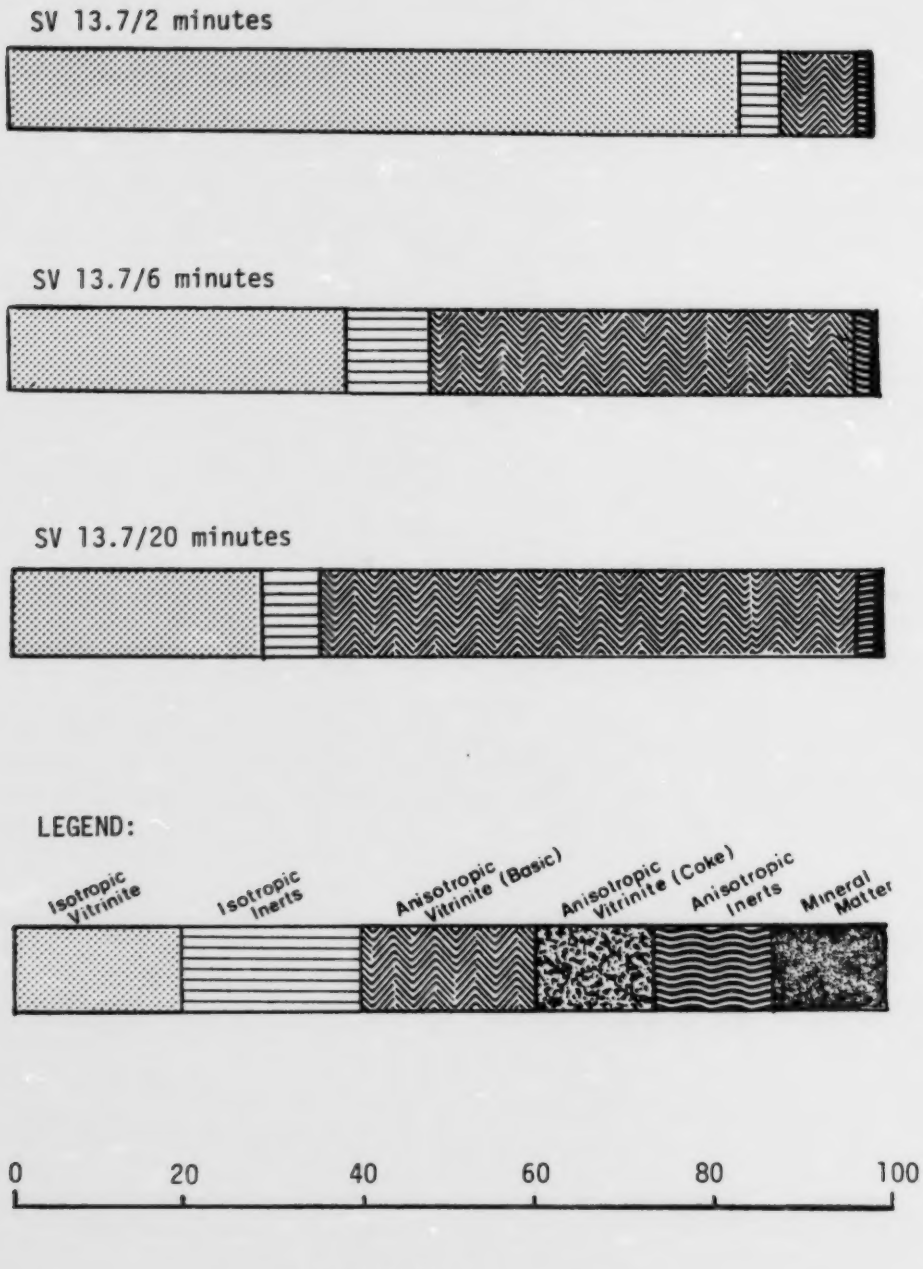


FIGURE 6.7

Petrographic analyses of gasification residues

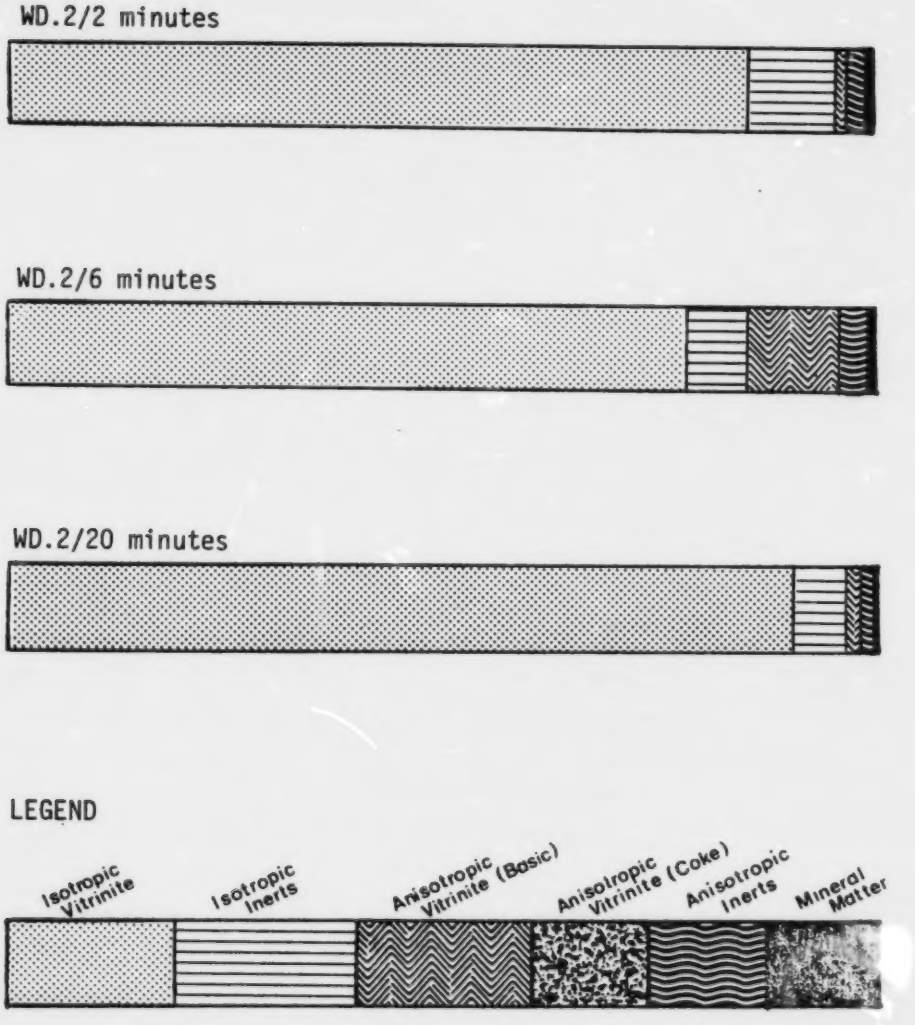


FIGURE 6.8

Petrographic analyses of gasification residues

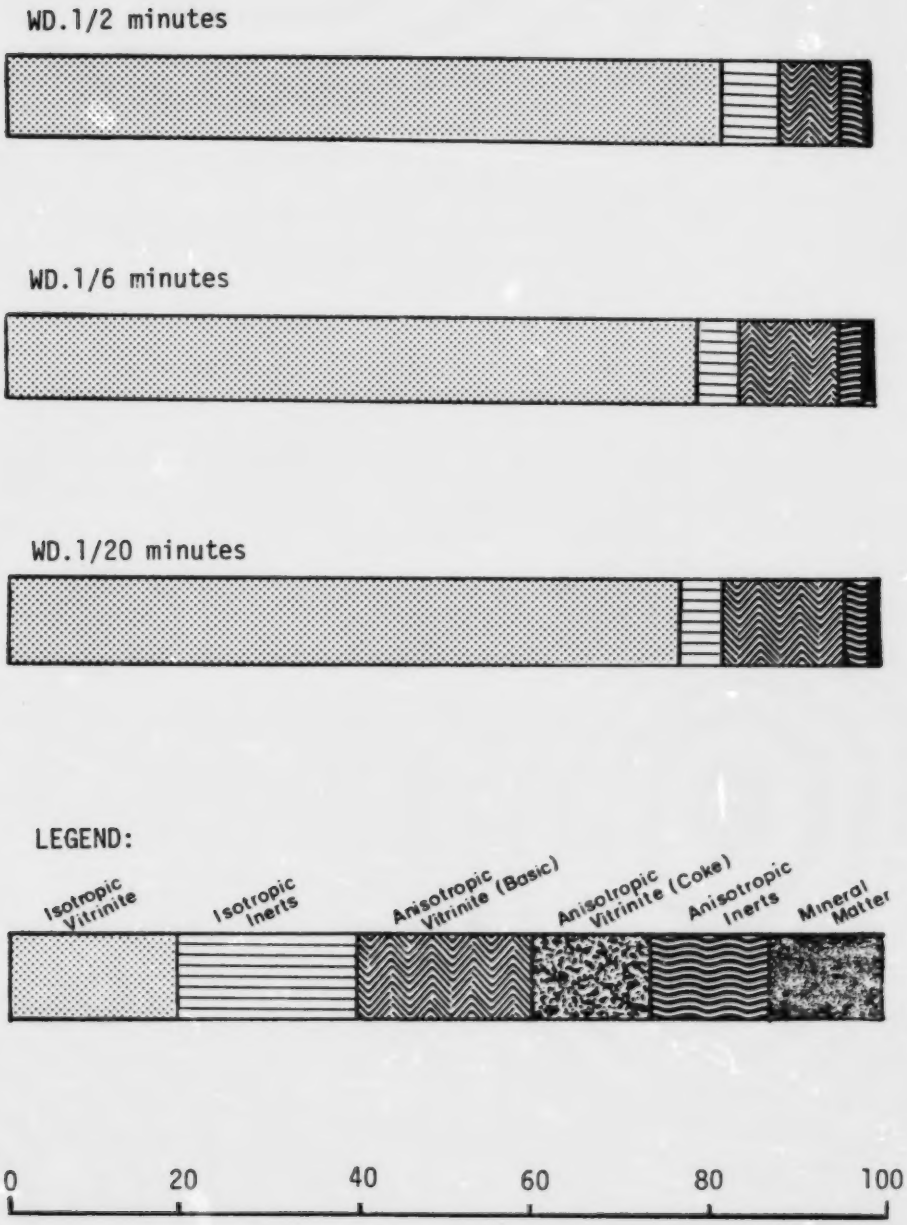


FIGURE 6.9

Petrographic analyses of gasification residues

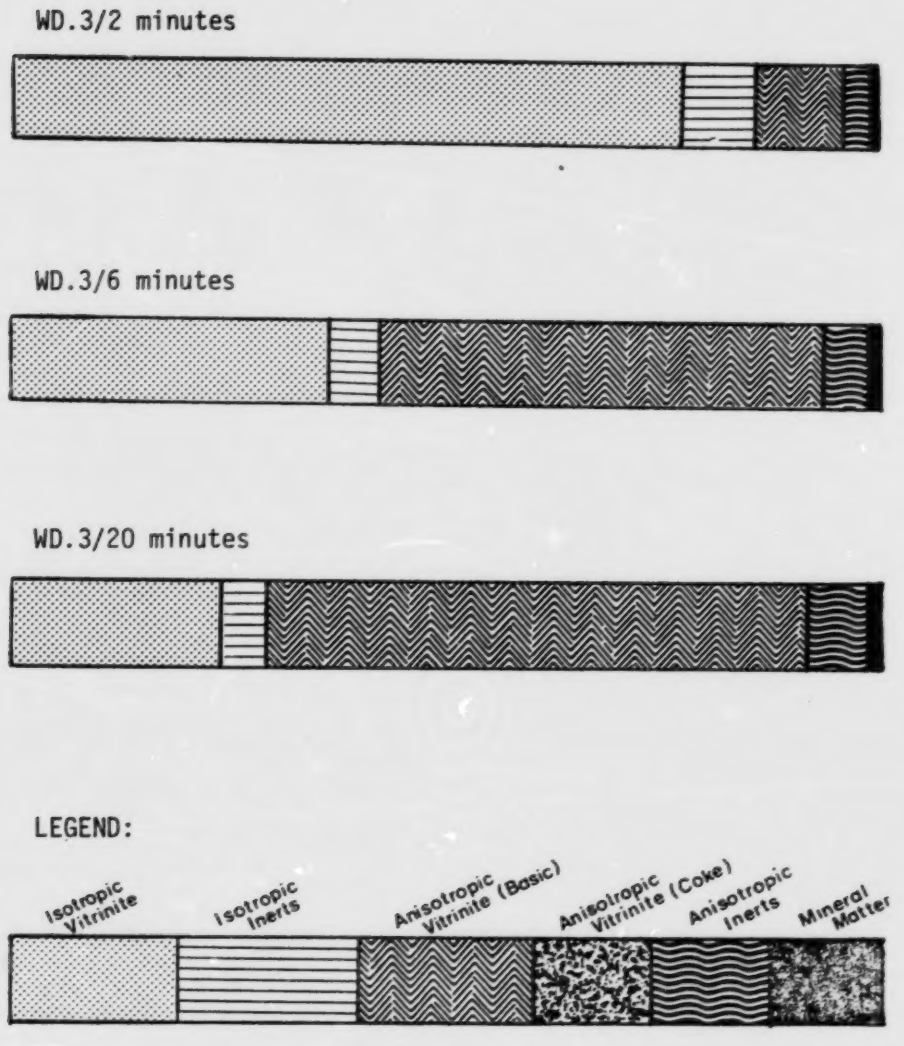


FIGURE 6.10

Petrographic analyses of gasification residues

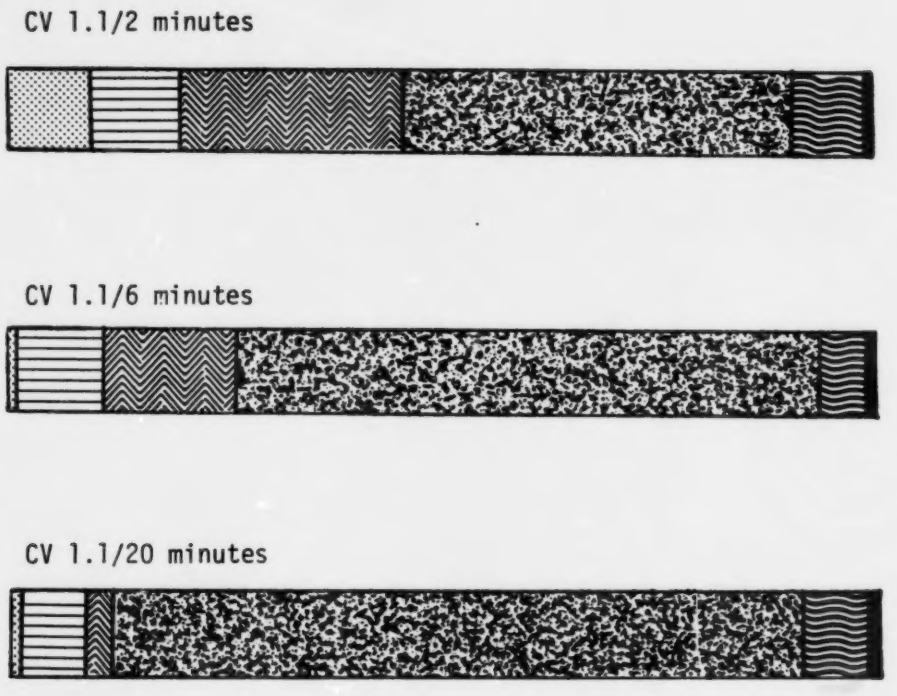


FIGURE 6.11

Petrographic analyses of gasification residues

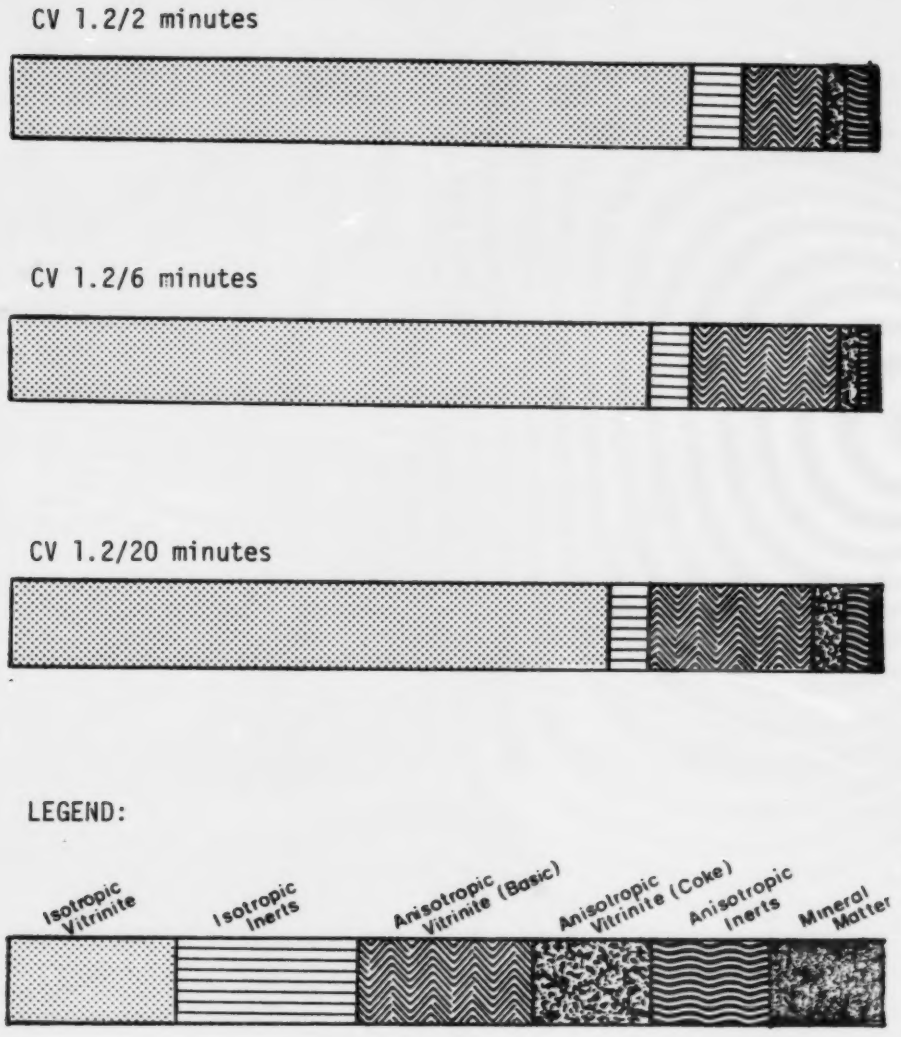
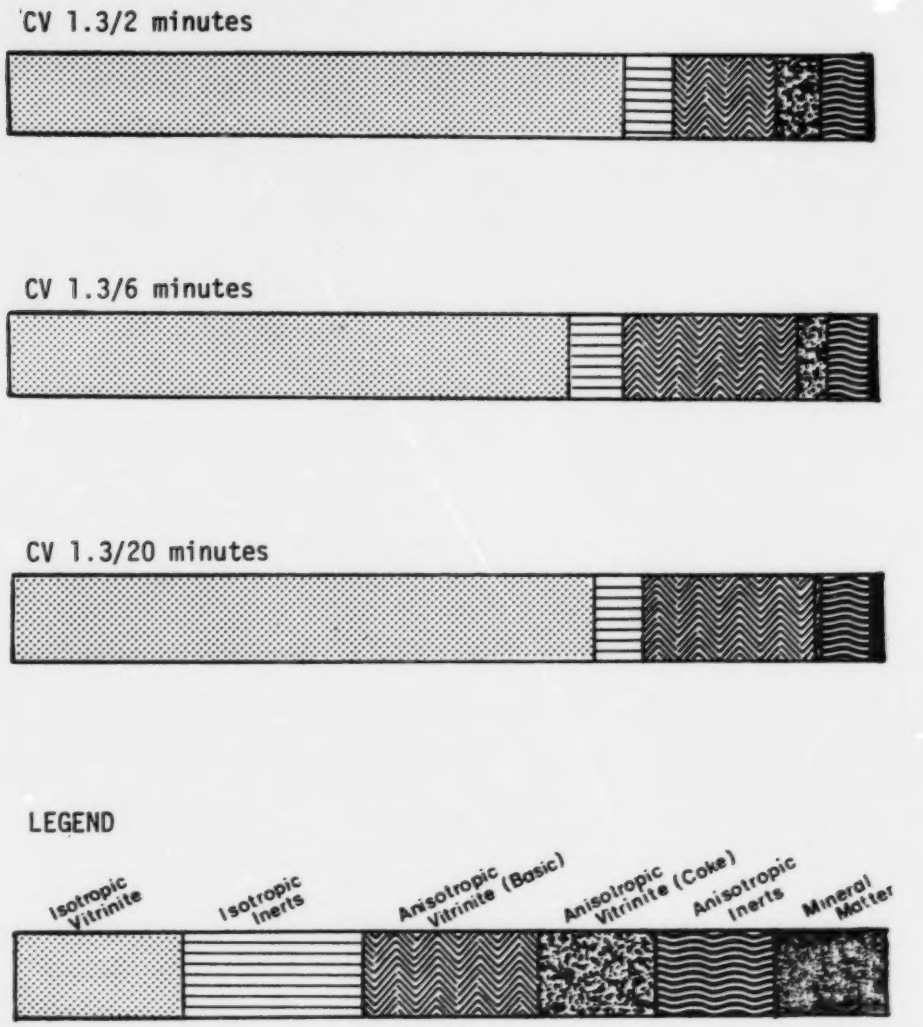


FIGURE 6.12

Petrographic analyses of gasification residues



Sample	Oxidising Conditions	Gasification: Residence Time	Mean Max. R_o	Mean Min. R_o	Bioreflectance	Correlation Coefficient
SV13.1	60 Hrs. 100°C	2 min.	1.09	0.99	0.10	0.90
SV13.1	60 Hrs. 100°C	6 min.	2.48	2.22	0.26	0.81
SV13.1	60 Hrs. 100°C	20 min.	4.34	3.83	0.51	0.26
SV13.6	20 Hrs. 225°C	2 min.	3.62	3.35	0.27	0.95
SV13.6	20 Hrs. 225°C	6 min.	5.25	4.86	0.39	0.91
SV13.6	20 Hrs. 225°C	20 min.	5.75	5.17	0.58	0.86
SV13.7	60 Hrs. 225°C	2 min.	2.17	1.94	0.23	0.96
SV13.7	60 Hrs. 225°C	6 min.	5.36	4.87	0.49	0.63
SV13.7	60 Hrs. 225°C	20 min.	5.05	4.31	0.74	0.56

Table 6.5 Reflectance and Bireflectance values for preoxidised gasification residues

Sample	Oxidising Conditions	Gasification: Residence Time	Mean Max. R_o	Mean Min. R_o	Bioreflectance	Correlation Coefficient
WD.2	60 Hrs. 100°C	2 min.	2.34	2.12	0.22	0.38
WD.2	60 Hrs. 100°C	6 min.	4.78	4.22	0.56	0.44
WD.2	60 Hrs. 100°C	20 min.	4.68	4.31	0.37	0.79
WD.1	20 Hrs. 225°C	2 min.	3.24	3.04	0.20	0.99
WD.1	20 Hrs. 225°C	6 min.	4.61	4.33	0.28	0.88
WD.1	20 Hrs. 225°C	20 min.	5.53	5.19	0.34	0.49
WD.3	60 Hrs. 225°C	2 min.	2.70	2.40	0.30	0.88
WD.3	60 Hrs. 225°C	6 min.	4.45	4.01	0.44	0.84
WD.3	60 Hrs. 225°C	20 min.	4.67	3.95	0.72	0.44

Table 6.6 Reflectance and Bireflectance values for preoxidised gasification residues

Sample	Oxidising Conditions	Gasification: Residence Time	Mean Max. R_O	Mean Min. R_O	Bioreflectance	Correlation Coefficient
CV1.1	60 Hrs. 100°C	2 min.	1.77	1.22	0.55	0.35
			4.01*	2.20*	1.81*	0.54
CV1.1	60 Hrs. 100°C	6 min.	4.88	3.99	0.89	0.65
			8.45*	5.68*	2.77*	0.44
CV1.1	60 Hrs. 100°C	20 min.	5.97	4.37	1.60	0.59
			10.95*	5.33*	5.62*	0.17
CV1.2	20 Hrs. 225°C	2 min.	2.37	2.07	0.30	0.94
CV1.2	20 Hrs. 225°C	6 min.	4.84	3.87	0.97	0.29
			8.71*	4.59*	4.12*	0.49
CV1.2	20 Hrs. 225°C	20 min.	6.45	4.27	2.18	0.65
CV1.3	60 Hrs. 225°C	2 min	2.86	2.25	0.61	0.74
CV1.3	60 Hrs. 225°C	6 min.	4.36	3.52	0.84	0.66
CV1.3	60 Hrs. 225°C	20 min.	1.73	1.49	0.24	

Table 6.7 Reflectance and bireflectance values for preoxidised gasification residues

Sample	Gasification Time	% Volatiles	%Ash	Calorific Value (J/g)
	2	31.1	11.6	26310
SV13.1	6	10.8	14.1	29330
	20	4.2	15.3	29790
	2	6.9	20.8	27050
SV13.6	6	2.7	21.5	26910
	20	2.9	21.3	26790
	2	16.1	24.6	24200
SV13.7	6	3.8	27.1	24700
	20	2.0	29.0	24610

Table 6.8 Proximate analyses of preoxidised gasification residues

Sample	Gasification Time	% Volatiles	%Ash	Calorific Value (J/g)
	2	14.5	9.0	29180
WD.2	6	0.6	10.8	30520
	20	1.6	10.0	30480
	2	1.7	9.8	30960
WD.1	6	1.5	11.1	30490
	20	11.6	7.5	30570
	2	16.4	15.7	25610
WD.3	6	0.7	20.3	26830
	20	-	17.8	27840

Table 6.9 Proximate analyses of preoxidised gasification residues

Sample	Gasification Time	% Volatiles	%Ash	Calorific Value (J/g)
	2	8.4	7.0	33240
CV1.1	6	2.7	11.5	31690
	20	0.3	9.2	30710
	2	15.0	10.2	30360
CV1.2	6	2.8	8.1	31120
	20	0.8	10.0	30760
	2	11.8	41.1	30320
CV1.3	6	3.9	16.8	31100
	20	1.3	10.9	30170

Table 6.10 Proximate analyses of preoxidised gasification residues

rims occurred in the preoxidised samples. The SV 13.1 preoxidised feedstock (oxidised for 60 hours at 100°C) did not display oxidation rims or cracks and there was little or no basic anisotropy developed in the gasification chars. Basic anisotropy also developed in the Whitewood gasification residues, although only those samples preoxidised for 60 hours at 225°C contained a higher proportion of anisotropic than isotropic material (Table 6.3). Whitewood coal preoxidised for 20 hours at 225°C, then gasified, contained less anistoropic material (10.5% to 17.2%) than the Souris Valley samples (29.0% to 60.6%) preoxidised and gasified under the same conditions.

After a short residence time (2 minutes) vesiculation was present in the groundmass huminite/vitrinite char; this may result from reaction of liptinites. After longer residence times (6 and 20 minutes) structured huminite/vitrinite became vesicular as well. The exception to this was when highly oxidised samples (oxidised for 60 hours at 225°C) were gasified for 20 minutes when little or no vesiculation of the gasification char occurred.

The CV samples contained two types of anisotropic material; one exhibiting basic anisotropy and the other a mosaic textured semicoke. Unlike the Souris Valley and Whiteood samples, the largest amount of anisotropic material in the CV samples was in the least severely oxidised feedstock. The amount of mosaic textured semicoke in the gasified products which had been oxidised for 60 hours at 100°C was in excess of 79% as opposed to less than 5% in samples oxidised for 20 and 60 hours at 225°C, indicating oxidation did retard anisotropic mosaic textured semicoke development.

The mean reflectance (R_0AV) of the vitrinite in the gasification chars increased with prolonged residence times; the reflectance marks an increase in the carbon content of the coal. A rapid increase in reflectance occurred between 2 and 6 minutes gasification, followed by a gradual increase, or a slight decrease in reflectance, after 20 minutes. The bireflectance, the difference between the mean maximum and the mean minimum reflectance, was also seen to increase. Bireflectance is a measure of the degree of anisotropy. Bireflectance values for Souris Valley and Whitewood samples generally increase with longer gasification times and were highest in chars from coals preoxidised for 60 hours at 225°C. The CV samples also had higher reflectances with longer residence times, however, the highest overall values were from samples preoxidised for 20 hours at 225°C.

Proximate analyses for the gasification residues are given in Tables 6.8 to 6.10. Compared to the preoxidised feedstocks (Table 6.1) the gasified products generally had lower volatile matter contents, a higher percentage of ash and higher calorific values, except for the gasification residues from CV1.1. In this sample the volatiles are lower, ash contents were higher and calorific values were lower than those of the preoxidised feedstock. These were the residues which contained large amounts of anisotropic, mosaic textured semicoke.

6.4 Petrography of Charred and Gasified Residues

In addition to gasification of lignite, sub-bituminous and bituminous coals which were oxidised under conditions described in Section 5.2, samples of each of these three coals were charred and then gasified. Samples of each of the original feedstocks (Souris Valley, White-

wood and CV) were charred for 60 minutes at 500°C in nitrogen, then gasified for 6 minutes at 800°C in an air/steam atmosphere. As well, samples of each of the feedstocks oxidised for 20 hours at 225°C were charred for 30 minutes at 500°C in nitrogen, then gasified for 6 minutes at 800°C in air/steam atmosphere. Petrographic analyses of these twelve samples are given in Tables 6.11 to 6.14.

6.4.1 Non-oxidised feedstocks, charred and gasified

Of the three original feedstocks which were charred, the Souris Valley and Whitewood samples appeared similar. They were dominantly isotropic, vesicular chars with minor amounts (approximately 6.0%) of anisotropic material, mainly inertinite and areas around vesicules in huminite/vitrinite. Both samples contained huminite/vitrinite material with reflectance (R_0AV) ranging from 1.6% to 3.2%. The CV char contained much more anisotropic material (52.0%), both basic anisotropy and mosaic textured semicoke, than the Whitewood or Souris Valley chars.

The gasified products of the Souris Valley and Whitewood samples appeared similar to the chars, dominantly isotropic and vesicular, but the reflectance had increased to 4.0%. When the CV char was gasified the resulting product was dominantly anisotropic (97.3%) with only a small amount of isotropic material (2.7%). The amount of material which displayed basic anisotropy was similar for both the char and the gasified product (27.7% and 24.7%); the material which displayed a mosaic texture increased from 12.7% in the char to 59.6% in the gasification residue and the amount of isotropic vitrinite dropped from 44.7% in the char to less than 1% in the gasified sample.

	SV 13.5	WD.4	CV 1.4
Isotropic Huminite/Vitrinite	91.4	87.6	44.7
Isotropic Inerts	2.5	6.0	3.3
Anisotropic (Basic) Huminite/ Vitrinite	2.6	2.4	27.7
Anisotropic (Mosaic) Huminite/ Vitrinite	-	-	12.7
Anisotropic Inerts	3.5	3.3	11.6
Mineral Matter	-	0.7	-
Total Vitrinite	94.0	90.0	85.1
Total Inerts	6.0	9.3	14.9
Total Mineral Matter	-	0.7	-
Total Isotropic	93.9	93.6	48.0
Total Anisotropic	6.1	5.7	52.0
Total Mineral Matter	-	0.7	-

TABLE 6.11 Petrographic analyses of original feedstocks: charred for 60 minutes at 500°C in N_2

	SV 13.8	WD.5	CV 1.5
Isotropic Huminite/Vitrinite	14.3	26.3	41.0
Isotropic Inerts	2.0	2.0	1.7
Anisotropic (Basic) Huminite/ Vitrinite	78.0	63.0	46.7
Anisotropic (Mosaic) Huminite/ Vitrinite	-	-	-
Anisotropic Inerts	5.4	8.4	10.3
Mineral Matter	0.3	0.3	0.3
Total Vitrinite	32.3	89.3	87.7
Total Inerts	7.4	10.4	12.0
Total Mineral Matter	0.3	0.3	0.3
Total Isotropic	16.3	28.3	42.7
Total Anisotropic	83.4	71.4	57.0
Total Mineral Matter	0.3	0.3	0.3

TABLE 6.12 Petrographic analyses of oxidised feedstocks: charred for 30 minutes at 500°C in N_2

Gasification Conditions 6 minutes at 800°C			
	SV 13.5	WD.4	CV 1.4
Isotropic Huminite/Vitrinite	89.5	87.4	0.7
Isotropic Inerts	4.6	2.5	2.0
Anisotropic (Basic) Huminite/ Vitrinite	3.5	4.6	24.7
Anisotropic (Mosaic) Huminite/ Vitrinite	-	-	59.6
Anisotropic Inerts	2.4	5.5	13.0
Mineral Matter	-	-	-
Total Vitrinite	93.0	92.0	85.0
Total Inerts	7.0	8.0	15.0
Total Mineral Matter	-	-	-
Total Isotropic	94.1	89.9	2.7
Total Anisotropic	5.9	10.1	2.7
Total Mineral Matter	-	-	-

TABLE 6.13 Petrographic analyses of original feedstocks: charred and gasified

Gasification Conditions 6 minutes at 800°C			
	SV 13.8	WD.5	CV 1.5
Isotropic Huminite/Vitrinite	1.3	1.7	3.3
Isotropic Inerts	1.0	0.7	0.3
Anisotropic (Basic) Huminite/ Vitrinite	88.0	85.7	80.4
Anisotropic (Mosaic) Huminite/ Vitrinite	-	-	6.3
Anisotropic Inerts	9.7	11.3	8.4
Mineral Matter	-	0.6	1.3
Total Vitrinite	89.3	87.4	90.0
Total Inerts	10.7	12.0	8.7
Total Mineral Matter	-	0.6	1.3
Total Isotropic	2.3	2.4	3.6
Total Anisotropic	97.3	97.0	95.1
Total Mineral Matter	-	0.6	1.3

TABLE 6.14 Petrographic analyses of original feedstocks: charred and gasified

6.4.2 Oxidised feedstocks, charred and gasified

The Souris Valley and Whiteood samples which were oxidised before charring differed from the non-oxidised, charred coals. These chars contained more than 70% anisotropic material, present as basic anisotropy. The chars were also vesicular and contained oxidation cracks (Plate 8), appearing similar to residues produced from gasification of the preoxidised coals (Section 6.3). The oxidised and non-oxidised, charred CV samples contained similar amounts of anisotropic material, 57.0% and 52.0%, respectively, but the oxidised char contained no mosaic textured semicoke. Micropores developed extensively and some oxidation cracks were present in the oxidised, charred sample.

After the Souris Valley and Whitewood samples were gasified the amount of anisotropic material increased to 97%, otherwise they appeared similar to the corresponding chars before gasification. The amount of anisotropic material also increased when the CV sample was gasified. Some mosaic semicoke did develop (6.0%) but the majority (80.4%) was the basic anisotropic type.

CHAPTER 7

RECOMMENDATIONS FOR FUTURE WORK

Coal macerals are derived from the different organic material (plants) that formed the coal, and have different chemical analyses, constitution and chemical reactivity. They react differently under the relatively mild conditions used to gasify or liquefy coal. Coals from different regions have been formed under different conditions, and will react differently.

This project was intiated because comparatively little was known about the detailed petrography of Western Canadian coals, and the chemical reactivity of the various macerals. We have investigated, during the three Phases of this work, some of the variations in petrographic composition that occur in lignites, sub-bituminous and bituminous coals. The different reactivities of the various macerals during oxidation, devolatilisalism and gasification were investigated. This required intensive work since these changes were not described in the literature for these coals, and the macerals had to be identified and correlated.

The initial intent was that the petrographic expertise that had been acquired would be used to analyse feedstocks and residues from bench or engineering scale gasification experiments, and develop petrography as a useful tool in predicting the gasification potential of various feestocks. In addition analysis of gasification residues would provide useful information about the conditions inside a gasifier.

Consequently the in-house gasification experiments were designed to produce, as clearly as possible samples for petrographic analysis that had been subjected to known conditions. They were not, in themselves, designed to produce significant new data.

The acquired expertise in analysing feestocks, oxidised feedstocks, devolatised coals and residue chars from gasification experiments can be utilised in two ways. One would be the orginial intention, already mentioned above, that is that samples from other contractions gasification experiments should be analysed, and interpreted. This would eventually enable the use of petrography to help predict the suitability of coals for gasification, and for different gasification and liquefacation processes. The second possibility is that the present petrographic expertise is extended by investigating a larger variety of coals under different conditions.

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APPENDIX I

Results of petrographic analyses

TABLE I-1

Petrographic analyses of preoxidised feedstocks

Sample	Souris Valley		
Oxidising Conditions	60 Hrs. 100°C	20 Hrs. 225°C	60 Hrs. 225°C
Maceral Group Analysis			
Huminite/Vitrinite:			
Structured	36.7	44.2	51.0
Unstructured	5.5	4.0	3.2
Groundmass	41.0	35.0	30.8
Liptinite	3.7	1.3	0.3
Inertinite	11.8	14.7	13.5
Mineral Matter	1.3	0.8	1.3
	100%	100%	100%

TABLE I-2

Petrographic analyses of preoxidised feedstocks

Sample	Whitewood		
Oxidising Conditions	60 Hrs. 100°C	20 Hrs. 225°C	60 Hrs. 225°C
Maceral Group Analysis			
Huminite/Vitrinite:			
Structured	69.0	68.0	68.5
Unstructured	5.7	2.2	3.2
Groundmass	12.0	13.8	15.0
Liptinite	0.5	0.8	0.3
Inertinite	12.1	14.2	12.5
Mineral Matter	0.7	1.0	0.5
	100%	100%	100%

TABLE I-3

Petrographic analyses of preoxidised feedstocks

Sample	CV		
Oxidising Conditions	60 Hrs. 100°C	20 Hrs. 225°C	60 Hrs. 225°C
Maceral Group Analysis			
Huminite/Vitrinite:			
Structured	48.5	50.1	51.2
Unstructured	1.5	1.0	0.5
Groundmass	30.7	31.5	31.0
Liptinite	-	-	-
Inertinite	19.3	17.1	17.1
Mineral Matter	-	0.3	0.2
	100%	100%	100%

TABLE I-4

Petrographic analyses of preoxidised gasification residues

Sample	SV13.1		
Oxidising Conditions	60 Hrs. 100°C		
Gasification: Residence Time	2 min.	6 min.	20 min.
Isotropic Huminite/Vitrinite	89.0	90.7	93.0
Isotropic Inerts	10.7	8.3	4.7
Anisotropic (Basic) Huminite/ Vitrinite	--	--	0.7
Anisotropic (Coke) Huminite/ Vitrinite	--	--	--
Anisotropic Inerts	--	0.7	1.0
Mineral Matter	0.3	0.3	0.6
Total Vitrinite	89.0	90.7	93.7
Total Inerts	10.7	9.0	5.7
Total Mineral Matter	0.3	0.3	0.6
Total Isotropic	99.7	99.0	97.7
Total Anisotropic	--	0.7	1.7
Total Mineral Matter	0.3	0.3	0.6

TABLE I-5

Petrographic analyses of preoxidised gasification residues

Sample	SV13.1		
Oxidising Conditions	20 Hrs. 225°C		
Gasification: Residence Time	2 min.	6 min.	20 min.
Isotropic Huminite/Vitrinite	63.3	48.0	31.7
Isotropic Inerts	7.4	4.7	7.7
Anisotropic (Basic) Huminite/ Vitrinite	27.0	46.0	59.6
Anisotropic (Coke) Huminite/ Vitrinite	--	--	--
Anisotropic Inerts	2.0	1.0	1.0
Mineral Matter	0.3	0.3	--
Total Vitrinite	90.3	94.0	91.3
Total Inerts	9.4	5.7	8.7
Total Mineral Matter	0.3	0.3	--
Total Isotropic	70.7	52.7	39.4
Total Anisotropic	29.0	47.0	60.6
Total Mineral Matter	0.3	0.3	--

TABLE I-6

Petrographic analyses of preoxidised gasification residues

Sample	SV13.1		
Oxidising Conditions	60 Hrs. 225°C		
Gasification: Residence Time	2 min.	6 min.	20 min.
Isotropic Huminite/Vitrinite	84.7	39.0	28.7
Isotropic Inerts	5.3	10.0	7.3
Anisotropic (Basic) Huminite/ Vitrinite	8.7	49.0	61.7
Anisotropic (Coke) Huminite/ Vitrinite	--	--	--
Anisotropic Inerts	1.0	1.7	2.0
Mineral Matter	0.3	0.3	0.3
Total Vitrinite	93.4	88.0	90.4
Total Inerts	6.3	11.7	9.3
Total Mineral Matter	0.3	0.3	0.3
Total Isotropic	90.0	49.0	36.0
Total Anisotropic	9.7	50.7	63.7
Total Mineral Matter	0.3	0.3	0.3

TABLE I-7

Petrographic analyses of preoxidised gasification residues

Sample	WD.2		
Oxidising Conditions	60 Hrs. 100°C		
Gasification: Residence Time	2 min.	6 min.	20 min.
Isotropic Huminite/Vitrinite	85.4	78.3	90.7
Isotropic Inerts	10.0	7.0	6.0
Anisotropic (Basic) Huminite/ Vitrinite	1.3	10.7	1.7
Anisotropic (Coke) Huminite/ Vitrinite	--	--	--
Anisotropic Inerts	3.0	3.7	1.3
Mineral Matter	0.3	0.3	0.3
Total Vitrinite	86.7	89.0	92.4
Total Inerts	13.0	10.7	7.3
Total Mineral Matter	0.3	0.3	0.3
Total Isotropic	95.4	85.3	96.7
Total Anisotropic	4.3	14.4	3.0
Total Mineral Matter	0.3	0.3	0.3

TABLE I-8

Petrographic analyses of preoxidised gasification residues

Sample	WD.1		
Oxidising Conditions	20 Hrs. 225°C		
Gasification: Residence Time	2 min.	6 min.	20 min.
Isotropic Huminite/Vitrinite	82.2	80.0	77.3
Isotropic Inerts	7.0	5.4	5.5
Anisotropic (Basic) Huminite/ Vitrinite	7.5	12.0	14.2
Anisotropic (Coke) Huminite/ Vitrinite	--	--	--
Anisotropic Inerts	3.0	2.0	3.0
Mineral Matter	0.3	0.6	--
Total Vitrinite	89.7	92.0	91.5
Total Inerts	10.0	7.4	8.5
Total Mineral Matter	0.3	0.6	--
Total Isotropic	89.2	85.4	82.8
Total Anisotropic	10.5	14.0	17.2
Total Mineral Matter	0.3	0.6	--

TABLE I-9

Petrographic analyses of preoxidised gasification residues

Sample	WD.1		
Oxidising Conditions	60 Hrs. 225°C		
Gasification: Residence Time	2 min.	6 min.	20 min.
Isotropic Huminite/Vitrinite	77.8	36.4	24.4
Isotropic Inerts	8.5	6.2	5.6
Anisotropic (Basic) Huminite/ Vitrinite	10.2	51.9	62.4
Anisotropic (Coke) Huminite/ Vitrinite	--	--	--
Anisotropic Inerts	2.7	4.5	6.0
Mineral Matter	0.8	1.0	1.6
Total Vitrinite	88.0	88.3	86.8
Total Inerts	11.2	10.7	11.6
Total Mineral Matter	0.8	1.0	1.6
Total Isotropic	86.3	42.6	30.0
Total Anisotropic	12.9	56.4	68.4
Total Mineral Matter	0.8	1.0	1.6

TABLE-I-10

Petrographic analysis of preoxidised gasification residues

Sample	CV1.1		
Oxidising Conditions	60 Hrs. 100°C		
Gasification: Residence Time	2 min.	6 min.	20 min.
Isotropic Huminite/Vitrinite	9.7	1.0	1.7
Isotropic Inerts	10.3	9.6	7.3
Anisotropic (Basic) Huminite/ Vitrinite	26.0	15.5	3.3
Anisotropic (Coke) Huminite/ Vitrinite	45.6	67.6	79.7
Anisotropic Inerts	7.7	5.6	7.0
Mineral Matter	0.7	0.7	1.0
Total Vitrinite	81.3	84.1	84.7
Total Inerts	18.0	15.2	14.3
Total Mineral Matter	0.7	0.7	1.0
Total Isotropic	20.0	10.6	9.0
Total Anisotropic	79.3	88.7	90.0
Total Mineral Matter	0.7	0.7	7.0

TABLE I-11

Petrographic analyses of preoxidised gasification residues

Sample	CV1.2		
Oxidising Conditions	20 Hrs. 225°C		
Gasification: Residence Time	2 min.	6 min.	20 min.
Isotropic Huminite/Vitrinite	78.5	74.0	70.0
Isotropic Inerts	6.0	5.0	4.5
Anisotropic (Basic) Huminite/ Vitrinite	10.0	17.5	19.5
Anisotropic (Coke) Huminite/ Vitrinite	2.5	2.0	3.0
Anisotropic Inerts	2.5	1.0	2.5
Mineral Matter	0.5	0.5	0.5
Total Vitrinite	91.0	93.5	92.5
Total Inerts	8.5	6.0	7.0
Total Mineral Matter	0.5	0.5	1.5
Total Isotropic	84.5	79.0	74.5
Total Anisotropic	15.0	20.5	25.0
Total Mineral Matter	0.5	0.5	0.5

TABLE I-12

Petrographic analyses of preoxidised gasification residues

Sample	CV1.3		
Oxidising Conditions	60 Hrs. 225°C		
Gasification: Residence Time	2 min.	6 min.	20 min.
Isotropic Huminite/Vitrinite	71.3	64.5	67.3
Isotropic Inerts	5.7	6.5	5.7
Anisotropic (Basic) Huminite/ Vitrinite	12.0	20.0	20.0
Anisotropic (Coke) Huminite/ Vitrinite	5.0	3.7	0.3
Anisotropic Inerts	5.7	5.0	6.0
Mineral Matter	0.3	0.3	0.7
Total Vitrinite	88.3	88.2	87.6
Total Inerts	11.4	11.5	11.7
Total Mineral Matter	0.3	0.3	0.7
Total Isotropic	77.0	71.0	73.0
Total Anisotropic	22.7	28.7	26.3
Total Mineral Matter	0.3	0.3	0.7

APPENDIX II

Results of gasification experiments

TABLE II-1

GASIFICATION OF COAL

Experiment Number: 201

Sample: SV-13-Feedstock Charred [+]

Conditions: Air/Steam at 700°C

Reactants

Feedstock = 9.98 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 8.24 g

Tar = 0.04 g

Total Gas* = 0.09 g

H_2 = 0.0003 g

CH_4 = 0.01 g

CO_2 = 0.07 g

CO = 0.004 g

[+] Charred: 60 min, 600°C, N_2

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_3+	CO_2	CO	
2	620	150	-	19.0	-	-	-	81.0	-	6.3
4	700	220	-	35.4	6.1	2.4	-	56.2	-	16.5
6	740	190	20.6	13.5	2.3	3.2	-	39.5	20.9	11.9
TOTAL	---	---	5.6	28.6	4.8	2.5		52.8	5.7	14.8

	C%	H%	N%
Char	60.9	2.0	1.1

Heating value, char (dry) = 28670 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-2

GASIFICATION OF COAL

Experiment Number: 202

Sample: SV-13.7 Preoxidised Feedstock-Charred [+]

Conditions: Air/Steam at 800°C

Reactants

Feedstock = 9.59 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 8.26 g

Tar = 0.03 g

Total Gas* = 0.80 g

H_2 = 0.06 g

CH_4 = 0.05 g

CO_2 = 0.27 g

CO = 0.42 g

[+] Charred: 60 min, 500 °C, N_2

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_{3+}	CO_2	CO	
2	570	240	-	-	-	-	-	98.2	1.8	0.2
4	720	700	53.9	6.2	-	-	-	10.4	29.5	10.9
6	800	330	77.9	2.9	-	-	-	1.1	18.0	11.1
TOTAL	---	---	56.6	5.5	-	-	-	10.9	26.9	10.7

		C%	H%	N%
Heating value, char (dry) = 23960 J g^{-1}	Char	51.8	1.8	2.2

*Excluding N_2, O_2 and H_2O

TABLE II-3

GASIFICATION OF COAL

Experiment Number: 203

Sample: SV-13.1 +

Conditions: Air/Steam at 700°C

Reactants

Feedstock = 11.53 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 10.19 g

Tar = 0.02 g

Total Gas* = 0.043 g

H_2 = - g

CH_4 = - g

CO_2 = 0.04 g

CO = 0.003 g

+ Oxidised: 60 hours, 100°C

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_{3+}	CO_2	CO	
1	300	180	-	-	-	-	-	94.7	5.3	0.6
2	430	240	-	-	-	-	-	83.7	16.3	1.7
TOTAL	---	---	-	-	-	-	-	87.9	12.1	1.3

	C%	H%	N%
Char	49.9	3.5	1.2

Heating value, char (dry) = 26310 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-4

GASIFICATION OF COAL

Experiment Number: 204

Sample: SV-13.1 [+]

Conditions: Air/Steam at 700°C

Reactants

Feedstock = 11.87 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 8.01 g

Tar = 0.09 g

Total Gas* = 1.04 g

H_2 = 0.01 g

CH_4 = 0.11 g

CO_2 = 0.66 g

CO = 0.19 g

[+] Oxidised: 60 hours, 100°C

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_{3+}	CO_2	CO	
2	450	350	-	2.0	-	-	-	85.0	12.9	2.0
4	590	350	21.4	20.9	3.5	3.5	-	28.0	18.6	15.7
6	640	350	34.6	21.3	2.7	1.10	-	24.1	14.2	14.4
TOTAL	---	---	18.7	17.6	2.9	1.9	-	37.7	17.7	12.4

	C%	H%	N%
Char	59.6	2.8	1.4

Heating value, char (dry) = 29330 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-5

GASIFICATION OF COAL

Experiment Number: 205

Sample: SV-13.1 +

Conditions: Air/Steam at 700°C

Reactants

Feedstock = 12.05 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 6.64 g

Tar = 0.19 g

Total Gas* = 2.34 g

H_2 = 0.08 g

CH_4 = 0.24 g

CO_2 = 1.06 g

CO = 0.73 g

+ Oxidised: 60 hours, 100°C

GAS ANALYSES

Time	Sample	Gas Flow	Composition of Gas, Mole %							Heating Value
min.	Temp. °C	mL min^{-1}	H_2	CH_4	C_2H_6	C_2H_4	C_{3+}	CO_2	CO	MJ m^{-3}
5	570	350	12.6	17.8	3.0	2.3	1.8	31.8	16.9	13.3
10	710	230	51.8	5.9	-	-	-	1.8	17.9	9.4
20	710	90	26.7	1.3	-	-	-	4.5	18.9	5.3
TOTAL	---	---	35.9	13.4	1.8	1.4	1.1	21.2	22.9	12.3

	C%	H%	N%
Char	61.7	0.9	1.3

Heating value, char (dry) = 29790 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-6

GASIFICATION OF COAL

Experiment Number: 206

Sample: SV-13.6 +

Conditions: Air/Steam at 800°C

Reactants

Feedstock = 10.00 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 6.47 g

Tar = 0.02 g

Total Gas* = 0.10 g

H_2 = 0.0006 g

CH_4 = 0.0009 g

CO_2 = 0.09 g

CO = 0.008 g

+ Oxidised: 20 hours, 225°C

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_{3+}	CO_2	CO	
1	670	105	-	0.3	-	-	-	84.5	15.3	1.7
2	710	260	20.5	3.8	0.7	0.4	-	62.0	12.6	5.4
TOTAL	---	---	11.7	2.3	0.4	0.2	-	71.7	13.8	3.8

	C%	H%	N%
Char	57.2	1.4	1.7

Heating value, char (dry) = 27050 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-7

GASIFICATION OF COAL

Experiment Number: 207

Sample: SV-13.6 +

Conditions: Air/Steam at 800°C

Reactants

Feedstock = 10.01 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 6.05 g

Tar = 0.09 g

Total Gas* = 0.29 g

H_2 = 0.006 g

CH_4 = 0.02 g

CO_2 = 0.18 g

CO = 0.08 g

+ Oxidised: 20 hours, 225°C

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_{3+}	CO_2	CO	
2	740	720	-	3.6	-	-	-	96.5	-	1.2
4	760	550	57.7	8.1	0.6	0.5	-	4.2	28.9	12.5
6	840	170	87.9	5.5	-	-	-	2.3	4.2	11.6
TOTAL	---	---	23.2	9.9	0.6	0.5	-	37.2	28.6	9.4

	C%	H%	N%
Char	62.4	1.0	2.0

Heating value, char (dry) = 26910 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-8

GASIFICATION OF COAL

Experiment Number: 208

Sample: SV-13.6 [+]

Conditions: Air/Steam at 800°C

Reactants

Feedstock = 9.99 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 5.29 g

Tar = 0.11 g

Total Gas* = 1.01 g

H_2 = 0.04 g

CH_4 = 0.03 g

CO_2 = 0.26 g

CO = 0.67 g

[+] Oxidised: 20 hours, 225°C

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_3+	CO_2	CO	
5	790	670	40.6	7.1	0.4	0.5	-	21.4	30.0	10.3
10	820	310	45.4	0.6	-	-	-	2.9	51.2	10.4
15	840	230	14.6	0.8	-	-	-	5.6	78.9	10.1
20	820	170	55.9	2.1	-	-	-	10.8	31.1	9.9
TOTAL	---	---	41.1	2.9	0.1	0.2	-	10.4	45.3	10.2

	C%	H%	N%
Char	60.6	0.9	1.7

Heating value, char (dry) = 26790 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-9

GASIFICATION OF COAL

Experiment Number: 209

Reactants

Feedstock = 10.00 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Sample: SV-13.7 +

Products

Char = 6.84 g

Tar = 0.02 g

Total Gas* = 0.72 g

Conditions: Air/Steam at 800°C

H_2 = 0.0005 g

CH_4 = 0.001 g

CO_2 = 0.66 g

CO = 0.06 g

+ Oxidised: 60 hours, 225°C

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_3+	CO_2	CO	
1	640	480	-	0.7	-	-	-	83.9	15.4	1.8
2	710	700	1.5	0.5	-	0.1	-	85.6	12.1	1.7
TOTAL	---	---	1.3	0.5	-	0.1	-	85.5	12.4	1.7

	C%	H%	N%
Char	52.9	2.0	2.2

Heating value, char (dry) = 24200 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-10

GASIFICATION OF COAL

Experiment Number: 210

Sample: SV-13.7 +

Conditions: Air/Steam at 800°C

Reactants

Feedstock = 9.99 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 5.78 g

Tar = 0.04 g

Total Gas* = 0.22 g

H_2 = 0.02 g

CH_4 = 0.03 g

CO_2 = 0.09 g

CO = 0.08 g

+ Oxidised: 60 hours, 225°C

GAS ANALYSES

Time	Sample	Gas Flow	Composition of Gas, Mole %							Heating Value
min.	Temp. °C	mL min^{-1}	H_2	CH_4	C_2H_6	C_2H_4	C_3+	CO_2	CO	MJ m^{-3}
2	750	720	26.8	3.8	-	-	-	58.6	10.8	5.2
4	820	510	58.3	10.4		-	-	4.6	26.8	12.4
6	840	490	69.5	11.3	-	-	-	3.1	16.2	12.8
TOTAL	---	---	56.9	9.5	-	-	-	13.9	19.7	11.3

	C%	H%	N%
Char	53.8	0.9	1.7

Heating value, char (dry) = 24700 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-11

GASIFICATION OF COAL

Experiment Number: 211

Sample: SV-13.7 +

Conditions: Air/Steam at 800°C

Reactants

Feedstock = 10.00 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 5.39 g

Tar = 0.06 g

Total Gas* = 0.66 g

H_2 = 0.04 g

CH_4 = 0.02 g

CO_2 = 0.35 g

CO = 0.25 g

+ Oxidised: 60 hours, 225°C

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_3^+	CO_2	CO	
5	780	720	86.8	4.9	-	-	-	2.6	5.7	11.4
10	850	240	43.1	2.7	-	-	-	3.9	50.3	10.7
15	830	120	21.6	0.8	-	-	-	1.8	75.8	10.5
20	810	110	6.6	0.5	-	-	-	2.9	90.1	10.3
TOTAL	---	---	61.9	2.7	-	-	-	3.5	31.9	10.8

	C%	H%	N%
Char	54.7	0.8	1.8

Heating value, char (dry) = 24610 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-12

GASIFICATION OF COAL

Experiment Number: 212

Sample: Whitewood-Feedstock Charred [+]

Conditions: Air/Steam at 800°C

Reactants

Feedstock = 9.99 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 8.89 g

Tar = 0.07 g

Total Gas* = 0.09 g

H_2 = 0.003 g

CH_4 = 0.01 g

CO_2 = 0.05 g

CO = 0.02 g

[+] Charred: 60 min, 500°C, N_2

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_3+	CO_2	CO	
2	630	170	-	5.7	-	-	-	94.3	-	1.9
4	750	250	26.2	19.4	1.6	0.9	-	30.4	20.5	12.8
6	820	230	46.2	16.6	0.5	0.5	-	14.9	21.5	13.2
TOTAL	---	---	32.4	18.3	1.2	0.8	-	26.2	20.5	12.9

	C%	H%	N%
Char	55.3	1.5	1.7

Heating value, char (dry) = 31710 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-13

GASIFICATION OF COAL

Experiment Number: 213

Reactants

Feedstock = 9.76 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Sample: Whitewood .3
Preoxidised Feedstock-Charred
Products

Char = 7.85 g

Tar = 0.06 g

Total Gas* = 0.58 g

Conditions: Air/Steam at 800°C

H_2 = 0.05 g

CH_4 = 0.04 g

CO_2 = 0.21 g

CO = 0.28 g

+ Charred: 60 min, 500°C, N_2

GAS ANALYSES

Time	Sample	Gas Flow	Composition of Gas, Mole %							Heating Value
min.	Temp. °C	mL min^{-1}	H_2	CH_4	C_2H_6	C_2H_4	C_3+	CO_2	CO	MJ m^{-3}
2	560	200	-	-	-	-	-	100	-	0.00
4	750	340	27.2	0.8	-	-	-	-	10.4	4.3
6	800	640	60.2	7.2	-	-	-	-	28.4	11.8
TOTAL	---	---	55.7	6.4	-	-	-	11.8	26.1	10.8

	C%	H%	N%
Char	50.1	2.3	1.7

Heating value, char (dry) = 28330 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-14

GASIFICATION OF COAL

Experiment Number: 214

Reactants

Feedstock = 10.00 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Sample: Whitewood .2 +

Products

Char = 7.49 g

Tar = 0.01 g

Total Gas* = 0.003 g

Conditions: Air/Steam at 800°C

H_2 = - g

CH_4 = 0.0008g

CO_2 = 0.002 g

CO = - g

+ Oxidised: 60 hours, 100°C

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_3+	CO_2	CO	
1	690	110	-	-	-	-	-	100.0	-	0.0
2	730	270	-	44.2	8.1	6.8	-	40.9	-	22.9
TOTAL	---	---	-	42.8	7.9	6.6	-	43.7	-	22.2

	C%	H%	N%
Char	58.0	2.3	1.1

Heating value, char (dry) = 29180 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-15

GASIFICATION OF COAL

Experiment Number: 215

Sample: Whitewood .2 +

Conditions: Air/Steam at 800°C

Reactants

Feedstock = 10.00 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 6.09 g

Tar = 0.06 g

Total Gas* = 0.57 g

H_2 = 0.04 g

CH_4 = 0.08 g

CO_2 = 0.11 g

CO = 0.31 g

+ Oxidised: 60 hours, 100°C

GAS ANALYSES

Time	Sample	Gas Flow	Composition of Gas, Mole %							Heating Value
min.	Temp. °C	mL min^{-1}	H_2	CH_4	C_2H_6	C_2H_4	C_3+	CO_2	CO	MJ m^{-3}
2	680	170	-	6.8	-	-	-	93.2	-	2.2
4	780	520	42.9	6.8	1.7	2.1	-	8.4	35.8	13.0
6	850	460	58.1	17.3	-	0.1	-	4.3	20.2	14.1
TOTAL	---	---	51.7	12.9	0.9	0.9	-	6.1	26.6	13.5

	C%	H%	N%
Char	64.2	0.9	0.8

Heating value, char (dry) = 30520 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-16

GASIFICATION OF COAL

Experiment Number: 216

Sample: Whitewood .2 +

Conditions: Air/Steam at 800°C

Reactants

Feedstock = 10.01 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 6.22 g

Tar = 0.11 g

Total Gas* = 0.62 g

H_2 = 0.04 g

CH_4 = 0.08 g

CO_2 = 0.37 g

CO = 0.11 g

+ Oxidised: 60 hours, 100°C

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_{3+}	CO_2	CO	
5	800	540	32.9	15.9	0.8	1.1	-	34.8	13.8	11.3
10	850	200	83.4	9.3	-	-	-	2.5	4.8	12.4
15	860	150	-	52.4	-	-	-	47.6	-	12.4
20	830	110	77.1	4.2	-	-	-	1.0	17.7	11.4
TOTAL	---	---	50.8	13.2	0.5	0.7	-	23.0	11.3	11.6

	C%	H%	N%
Char	64.9	0.8	0.8

Heating value, char (dry) = 30480 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-17

GASIFICATION OF COAL

Experiment Number: 217

Sample: Whitewood .1 +

Conditions: Air/Steam at 800°C

Reactants

Feedstock = 9.99 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 7.14 g

Tar = 0.25 g

Total Gas* = 0.004 g

H_2 = - g

CH_4 = 0.00006 g

CO_2 = 0.004 g

CO = - g

+ Oxidised: 20 hours, 225°C

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_{3+}	CO_2	CO	
1	750	100	-	-	-	-	-	100	-	0.0
2	810	120	-	34.4	-	-	-	67.6	-	10.7
TOTAL	---	---	-	28.7	-	-	-	71.3	-	7.5

	C%	H%	N%
Char	61.1	2.0	1.2

Heating value, char (dry) = 30960 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-18

GASIFICATION OF COAL

Experiment Number: 218

Sample: Whitewood .1 +

Conditions: Air/Steam at 800°C

Reactants

Feedstock = 10.00 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 6.72 g

Tar = 0.12 g

Total Gas* = 0.009 g

H_2 = - g

CH_4 = 0.0008 g

CO_2 = 0.008 g

CO = - g

+ Oxidised: 20 hours, 225°C

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_3+	CO_2	CO	
2	760	120	-	-	-	-	-	100.0	-	0.0
4	830	260	-	-	-	-	-	100.0	-	0.0
6	850	290	-	45.4	-	-	-	54.6	-	15.0
TOTAL	---	---	-	21.2	-	-	-	78.8	-	8.8

	C%	H%	N%
Char	66.3	1.2	1.0

Heating value, char (dry) = 30490 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-19

GASIFICATION OF COAL

Experiment Number: 219

Sample: Whitewood .1 +

Conditions: Air/Steam at 800°C

Reactants

Feedstock = 9.99 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 6.65 g

Tar = 0.07 g

Total Gas* = 0.15 g

H_2 = 0.007 g

CH_4 = 0.04 g

CO_2 = 0.09 g

CO = - g

+ Oxidised: 20 hours, 225°C

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_{3+}	CO_2	CO	
5	790	350	-	46.5	-	-	-	53.5	-	15.4
10	840	620	46.2	25.4	2.1	2.4	-	23.9	-	15.8
15	840	200	-	58.0	-	-	-	41.9	-	19.2
20	850	110	-	31.3	-	-	-	68.7		10.4
TOTAL	---	---	43.5	26.9	2.0	2.3	-	25.4	-	15.9

	C%	H%	N%
Char	66.1	0.7	0.8

Heating value, char (dry) = 30570 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-20

GASIFICATION OF COAL

Experiment Number: 220

Sample: Whitewood .3 +

Conditions: Air/Steam at 800°C

Reactants

Feedstock = 9.96 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 6.42 g

Tar = 0.04 g

Total Gas* = 0.19 g

H_2 = - g

CH_4 = 0.0007g

CO_2 = 0.19 g

CO = - g

+ Oxidised: 60 hours, 225°C

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_{3+}	CO_2	CO	
1	730	500	-	-	-	-	-	100.0	-	0.0
2	790	650	-	2.7	-	-	-	97.3	-	0.9
TOTAL	---	---	0.9					99.0		0.3

	C%	H%	N%
Char	58.4	1.9	2.0

Heating value, char (dry) = 25610 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-21

GASIFICATION OF COAL

Experiment Number: 221

Sample: Whitewood .3 +

Conditions: Air/Steam at 800°C

Reactants

Feedstock = 9.99 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 5.34 g

Tar = 0.04 g

Total Gas* = 0.43 g

H_2 = 0.002 g

CH_4 = 0.01 g

CO_2 = 0.35 g

CO = 0.06 g

+ Oxidised: 60 hours, 225°C

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_3+	CO_2	CO	
2	660	500	-	7.8	-	-	-	92.2	-	0.8
4	780	630	14.4	6.8	-	-	-	56.9	22.2	6.1
6	830	490	13.2	21.1	-	-	-	19.9	45.7	13.2
TOTAL	---	---	6.6	6.3	-	-	-	67.5	19.6	4.8

	C%	H%	N%
Char	60.4	0.5	0.9

Heating value, char (dry) = 26830 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-22

GASIFICATION OF COAL

Experiment Number: 222

Sample: Whitewood .3 +

Conditions: Air/Steam at 800°C

Reactants

Feedstock = 9.99 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 5.14 g

Tar = 0.05 g

Total Gas* = 1.26 g

H_2 = 0.05 g

CH_4 = 0.04 g

CO_2 = 0.89 g

CO = 0.28 g

+ Oxidised: 60 hours, 225°C

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_3+	CO_2	CO	
5	750	620	10.2	1.9	-	-	-	76.9	10.8	2.9
10	840	410	73.4	8.7	-	-	-	3.3	14.6	12.2
15	860	160	51.5	2.2	-	-	-	1.9	44.3	10.9
20	850	130	26.2	0.1	-	-	-	0.6	73.1	10.5
TOTAL	---	---	40.4	4.5	-	-	-	36.7	18.4	7.7

	C%	H%	N%
Char	63.3	0.6	1.1

Heating value, char (dry) = 27840 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-23

GASIFICATION OF COAL

Experiment Number: 223

Sample: CV-1 Feedstock Charred [+]

Conditions: Air/Steam at 800°C

Reactants

Feedstock = 9.99 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 8.94 g

Tar = 0.06 g

Total Gas* = 0.19 g

H_2 = 0.02 g

CH_4 = 0.11 g

CO_2 = 0.03 g

CO = 0.01 g

[+] Charred: 60 min, 500°C, N_2

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_3+	CO_2	CO	
2	590	170	-	-	-	-	-	100.0	-	0.0
4	670	380	38.8	46.7	4.6	0.5	-	6.5	2.1	22.7
6	780	280	70.8	24.9	0.8	0.2	-	0.6	2.6	16.6
20										
TOTAL	---	---	59.2	32.5	2.1	0.3	-	3.2	2.4	18.7
					C%	H%	N%			

Heating value, char (dry) = 31810 J g^{-1} Char none combustible samples

*Excluding N_2, O_2 and H_2O

TABLE II-24

GASIFICATION OF COAL

Experiment Number: 224

Sample: CV-1-1.3 Preoxidised Conditions: Air/Steam at 800°C
Feedstock-Charred +

Reactants

Feedstock = 9.79 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 8.55 g

Tar = 0.14 g

Total Gas* = 0.45 g

H_2 = 0.04 g

CH_4 = 0.05 g

CO_2 = 0.18 g

CO = 0.18 g

+ Charred: 60 min, 500°C, N_2

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_3+	CO_2	CO	
2	610	150	-	-	-	-	-	100.0	-	0.0
4	760	230	11.3	9.8	-	-	-	35.9	43.1	8.9
6	830	450	77.2	8.2	-	-	-	2.4	12.3	12.2
TOTAL	---	---	62.7	8.5	-	-	-	10.1	18.7	11.4

	C%	H%	N%
Char	66.5	2.0	1.0

Heating value, char (dry) = 29910 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-25

GASIFICATION OF COAL

Experiment Number: 225

Sample: CV-1.1 +

Conditions: Air/Steam at 800°C

Reactants

Feedstock = 10.00 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 9.32 g

Tar = 0.07 g

Total Gas* = 0.008 g

H_2 = 0.0004 g

CH_4 = 0.004 g

CO_2 = 0.002 g

CO = - g

+ Oxidised: 60 hours, 100°C

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_3+	CO_2	CO	
1	610	120	62.3	18.1	-	-	-	19.6	-	12.6
2	680	210	35.5	46.5	6.1	2.2	-	9.7	-	23.9
TOTAL	---	---	36.8	45.1	5.8	2.0	-	10.2	-	2.3

C% H% N%

Heating value, char (dry) = 33240 J g^{-1} Char none combustible sampes

*Excluding N_2, O_2 and H_2O

TABLE II-26

GASIFICATION OF COAL

Experiment Number: 226

Sample: CV-1.1 +

Conditions: Air/Steam at 800°C

Reactants

Feedstock = 10.00 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 8.57 g

Tar = 0.08 g

Total Gas* = 0.08 g

H_2 = 0.002 g

CH_4 = 0.03 g

CO_2 = 0.02 g

CO = 0.02 g

+ Oxidised: 60 hours, 100°C

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_3+	CO_2	CO	
2	630	190	45.9	29.6	4.1	3.6	-	16.9	-	18.9
4	780	310	57.9	35.0	1.9	2.1		3.1	-	19.9
6	820	250	66.2	24.6	0.4	0.4	-	2.3	6.1	16.3
TOTAL	---	---	29.5	43.2	2.3	2.3	-	8.6	14.1	14.5

	C%	H%	N%	
Char				none combustible samples

Heating value, char (dry) = 31690 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-27

GASIFICATION OF COAL

Experiment Number: 227

Sample: CV-1.1 +

Conditions: Air/Steam at 800°C

Reactants

Feedstock = 10.00 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 8.27 g

Tar = 0.08 g

Total Gas* = 0.39 g

H_2 = 0.02 g

CH_4 = 0.16 g

CO_2 = 0.08 g

CO = 0.09 g

+ Oxidised: 60 hours, 100°C

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_3+	CO_2	CO	
5	700	360	31.2	47.8	-	-	-	3.9	8.0	25.1
10	790	220	47.9	26.8	6.3	2.9		7.9	16.7	16.1
15	840	120	51.7	2.2	0.4	0.3	-	15.9	30.1	9.4
20	810	120	45.3	2.4	-	-	-	21.7	30.5	8.8
TOTAL	---	---	36.4	37.1	4.4	2.0	-	7.1	12.9	21.1
					C%	H%	N%			

Heating value, char (dry) = 30710 J g^{-1} Char none combustible samples

*Excluding N_2, O_2 and H_2O

TABLE II-28

GASIFICATION OF COAL

Experiment Number: 228

Sample: CV-1.2 +

Conditions: Air/Steam at 800°C

Reactants

Feedstock = 10.00 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 9.02 g

Tar = 0.06 g

Total Gas* = 0.14 g

H_2 = 0.0002g

CH_4 = 0.006 g

CO_2 = 0.12 g

CO = 0.01 g

+ Oxidised: 20 hours, 225°C

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_{3+}	CO_2	CO	
1	580	200	31.3	41.4	5.2	1.9	-	20.2	-	21.1
2	630	240	-	2.2	-	-	-	71.9	26.0	3.4
TOTAL	---	---	2.8	9.9	0.5	0.2	-	73.7	12.8	5.3

	C%	H%	N%
Char	65.9	3.5	1.0

Heating value, char (dry) = 30360 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-29

GASIFICATION OF COAL

Experiment Number: 229 | Sample: CV-1.2 [+] | Conditions: Air/Steam at 800°C

Reactants		Products			
Feedstock =	9.99 g	Char =	7.78 g	H_2 =	0.009 g
Oxygen Flow	0.13 g min^{-1}	Tar =	0.10 g	CH_4 =	0.06 g
Steam Flow	0.26 g min^{-1}	Total Gas* =	0.53 g	CO_2 =	0.26 g
				CO =	0.20 g

[+] Oxidised: 20 hours, 225°C

GAS ANALYSES

Time	Sample	Gas Flow	Composition of Gas, Mole %							Heating Value
min.	Temp. °C	mL min^{-1}	H_2	CH_4	C_2H_6	C_2H_4	C_3+	CO_2	CO	MJ m^{-3}
2	680	150	-	3.3	0.5	0.4	-	71.9	23.9	4.1
4	690	280	15.5	16.2	0.7	0.5	-	31.3	35.7	11.4
6	790	170	45.3	20.0	-	-	-	8.8	25.9	14.2
TOTAL	---	---	22.46	16.6	0.5	0.4	-	27.5	32.6	11.8

	C%	H%	N%
Char	70.2	1.5	1.1

Heating value, char (dry) = 31120 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-30

GASIFICATION OF COAL

Experiment Number: 230

Sample: CV-1.2 †

Conditions: Air/Steam at 800°C

Reactants

Feedstock = 10.00 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 7.27 g

Tar = 0.23 g

Total Gas* = 1.33 g

H_2 = 0.07 g

CH_4 = 0.10 g

CO_2 = 0.60 g

CO = 0.56 g

† Oxidised: 20 hours, 225°C

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_3+	CO_2	CO	
5	720	280	19.7	13.5	4.1	0.3	-	28.7	33.7	12.7
10	780	260	86.4	3.9	-	-	-	3.8	5.9	11.1
15	820	200	65.0	2.8	-	-	-	6.8	25.4	10.5
20	820	130	53.7	3.6	-	-	-	8.1	34.6	10.5
TOTAL	---	---	48.4	8.3	0.2	0.1	-	16.8	26.2	10.8

	C%	H%	N%
Char	73.1	0.6	1.0

Heating value, char (dry) = 30760 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-31

GASIFICATION OF COAL

Experiment Number: 231

Sample: CV-1.3 +

Conditions: Air/Steam at 800°C

Reactants

Feedstock = 9.99 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 8.12 g

Tar = 0.04 g

Total Gas* = 0.13 g

H_2 = - g

CH_4 = 0.0009 g

CO_2 = 0.11 g

CO = 0.02 g

+ Oxidised: 60 hours, 225°C

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_3+	CO_2	CO	
1	520	170	-	0.8	-	-	-	90.1	9.0	1.2
2	640	200	-	-	-	-	-	67.7	32.3	3.4
TOTAL	---	---	-	1.8	-	-	-	75.6	22.7	2.9

	C%	H%	N%
Char	70.0	2.1	1.0

Heating value, char (dry) = 30320 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-32

GASIFICATION OF COAL

Experiment Number: 232

Sample: CV-1.3 +

Conditions: Air/Steam at 800°C

Reactants

Feedstock = 10.01 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 7.46 g

Tar = 0.07 g

Total Gas* = 1.12 g

H_2 = 0.006 g

CH_4 = 0.04 g

CO_2 = 0.68 g

CO = 0.37 g

+ Oxidised: 60 hours, 225°C

GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_3+	CO_2	CO	
2	680	120	1.2	2.4	0.5	0.2	-	70.2	25.5	3.9
4	740	350	4.6	5.8	0.4	0.1	-	53.6	35.2	6.4
6	800	200	17.8	11.8	0.1	0.1	-	22.9	47.3	10.9
TOTAL	---	---	8.5	7.4	0.3	0.1	-	45.3	38.2	7.6

	C%	H%	N%
Char	72.3	1.4	1.2

Heating value, char (dry) = 31106 J g^{-1}

*Excluding N_2, O_2 and H_2O

TABLE II-33

GASIFICATION OF COAL

Experiment Number: 233

Sample: CV-1.3 [+]

Conditions: Air/Steam at 800°C

Reactants

Feedstock = 10.02 g

Oxygen Flow 0.13 g min^{-1}

Steam Flow 0.26 g min^{-1}

Products

Char = 6.81 g

Tar = 0.22 g

Total Gas* = 0.69 g

H_2 = 0.05 g

CH_4 = 0.03 g

CO_2 = 0.36 g

CO = 0.25 g

[+] Oxidised: 60 hours, 225°C

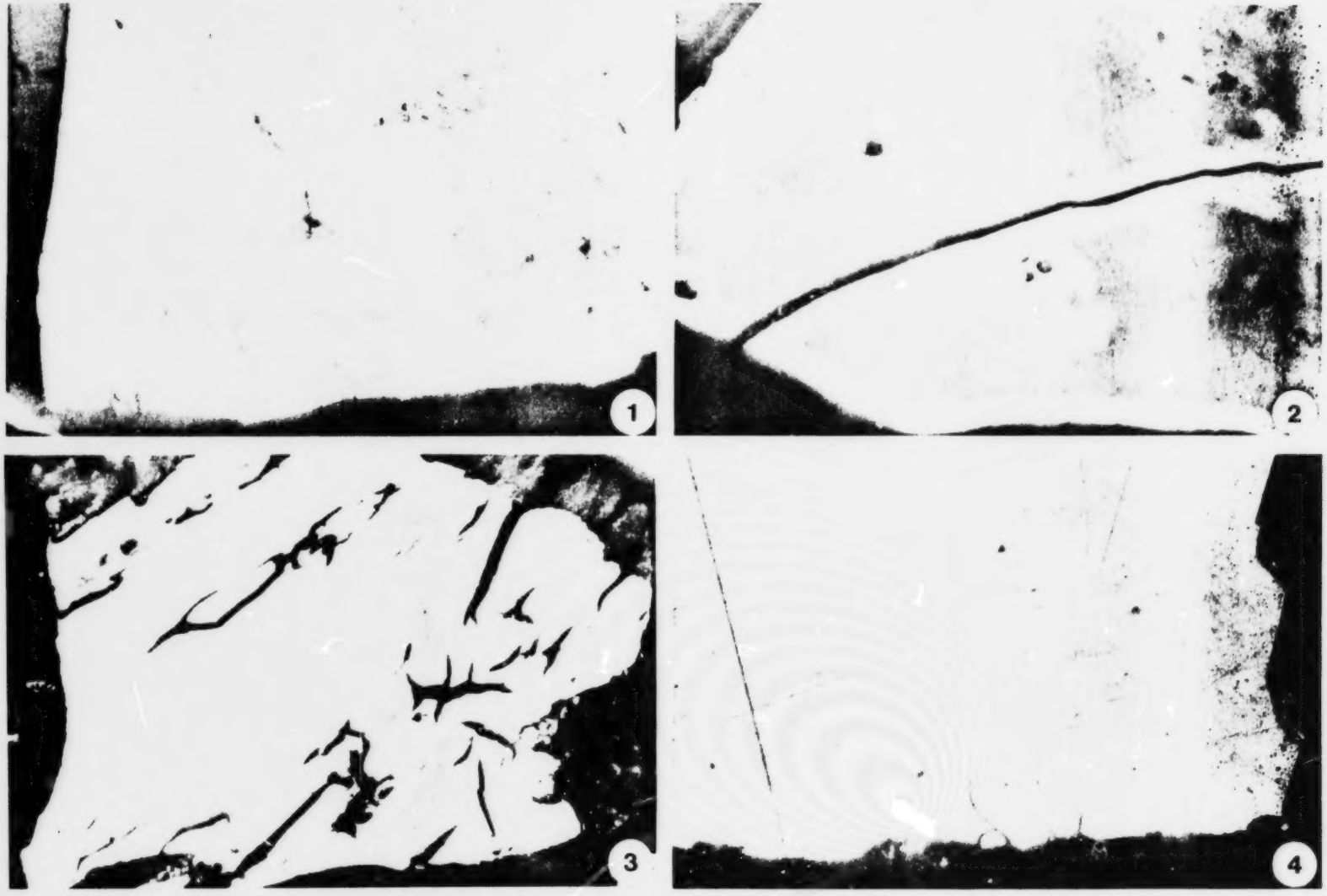
GAS ANALYSES

Time min.	Sample Temp. °C	Gas Flow mL min^{-1}	Composition of Gas, Mole %							Heating Value MJ m^{-3}
			H_2	CH_4	C_2H_6	C_2H_4	C_3+	CO_2	CO	
5	690	360	-	3.6	-	-	-	64.5	31.9	4.5
10	800	230	81.6	6.8	-	-	-	2.1	8.8	11.8
15	820	200	50.7	0.6	-	-	-	17.7	30.9	8.9
20	830	130	30.5	0.7	-	-	-	33.3	35.5	7.2
TOTAL	---	---	56.2	4.1	-	-	-	18.9	20.8	9.5

	C%	H%	N%
Char	72.3	1.4	1.2

Heating value, char (dry) = 30170 J g^{-1}

*Excluding N_2, O_2 and H_2O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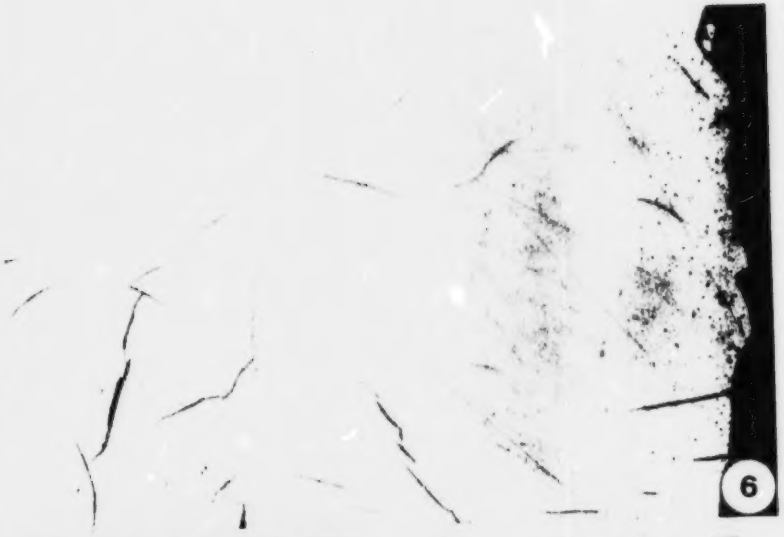
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